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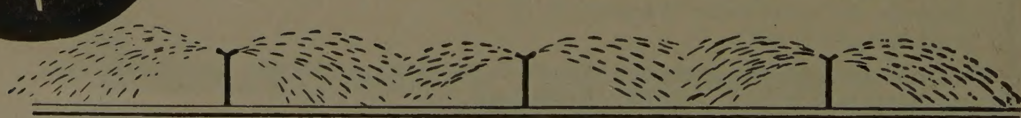

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EAST AFRICAN AGRICULTURAL AND FORESTRY JOURNAL

A PRELIMINARY SURVEY OF THE NITRATE CONTENT OF VARIOUS GRASSES

By K. W. Harker and A. K. Kamau, Animal Health Research Centre, Entebbe

(*Received for publication on 10th March, 1961*)

In the tropics, during the first few weeks after the commencement of the rainy season, cattle tend to lose condition and milk yields tend to drop, particularly if no feed is given to supplement grazing. In temperate regions similar reactions of livestock occur after the autumn flush of new grass. Numerous theories have been formulated to explain these occurrences. One of these is that during warm, dry weather there is an accumulation of nitrate nitrogen in the soil and when rain falls the nitrate is absorbed quickly by the plants (Ferguson and Terry, 1956). Animals consuming material with a high nitrate content would tend to lose condition, to fall off in milk production and in severe cases to die. (Whitehead and Moxon, 1952).

In Uganda, it has been shown that the nitrate content of the soil can be high in the top soil at certain seasons of the year (Ap. Griffith and Manning, 1949) and cattle fall off in condition early in the rains, but it is necessary to prove the presence or absence of nitrate nitrogen in local herbage. Consequently, it was decided to conduct a number of spot tests to ascertain the position.

Materials and Methods

The samples used for testing were taken from grasses growing wild or growing in plant introduction plots. All the samples were collected within a radius of half a mile of the laboratory and were tested immediately.

The testing procedure was to use the sample to stir eight drops of a solution of 0.12 gm. diphenyl-amine in 100 c.c. pure sulphuric acid, in the hollow of a white porcelain tile, for about one minute. If nitrate was present a blue colour developed. The intensity of colour is roughly proportional to the concentration of nitrate, within the range 5-25 p.p.m. of the test solution (Spurway, 1944).

The first tests were conducted on 13th March, 1958, six hours after a 1.8 in. rain storm, following four days without any rain. Further tests were carried out 24 hours later and after a further 48 hours. Opportunities for further testing of species did not arise until 23rd and 24th November, 1959.

In the earlier tests, *Pennisetum purpureum* gave more positive results than any other species, and work was concentrated on this species. At first the cut surface of each sample was used for stirring. On 19th March, 1959, however, a shoot was dissected and the base of each leaf was tested. The results indicated that there could be a range of nitrate levels in the same shoot. To follow up this finding in more detail it was decided to test the leaf blades and the sheaths at two-inch intervals. The complete leaf was cut into two-inch lengths and the lower surface of each length was tested for the presence of nitrate. In this way 12 complete shoots of one strain of *P. purpureum* were tested between 19th and 21st March.

Opportunities for further tests did not occur until 24th October. There was very little rain in September and the early half of October, but a shower started on the morning of the 24th and it was therefore decided to test the nitrate content of *P. purpureum* before rain had any effect and to repeat the tests later. To overcome the difficulties of distribution within the shoot, each leaf was tested at the base of the sheath, at the base of the blade and half way along the blade.

The rains did not continue in October and further tests were not conducted until 1st December. Extensive testing, to try and find some relationship between stage of growth of *P. Purpureum*, climatic conditions and the nitrate content of the herbage were started on 23rd November, 1959.

Results

The results of the species survey are summarized in Table I. The three numbers opposite each species give the number of samples tested, the number of samples with some nitrate present and the number of samples with a nitrate content of more than 25 p.p.m. respectively.

Between 19th and 21st March, 1959, the material from 12 complete shoots of *P. purpureum* was tested at 2-in. intervals.

The results were not consistent from shoot to shoot, but they showed a similar pattern of gradation from high to no nitrate. The results for two shoots, scored from 0 (no nitrate) to 3 (high nitrate) are given in Table II.

Four shoots were tested on 24th October. Three were completely negative. In the fourth shoot the leaf sheath of the outer leaf and the blade base of two inner leaves were positive. The following day a further four shoots were tested. All shoots were positive and gave the following totals. Leaf sheaths: 25 tested, 20 positive; blade bases: 35 tested, 22 positive and centre blade: 35 tested, 2 positive. These results indicate the speed of change of the nitrate content of leaves.

In December, 1958, material from three different strains of *P. purpureum* was tested. On 8th December one strain gave positive material, but the two other strains were completely negative. Ten days later, after 3.26 in. of rain, the same three strains were tested. The previously positive strain was completely negative, but the inner leaves of the two other strains gave positive tests.

Before the extensive testing of *P. purpureum* started an area of Uganda hairless strain was managed to give a sequence of shoots of different sizes, at approximately weekly intervals. The results summarized in Table III show the percentage of tests with a nitrate content of over 25 p.p.m., for different sized shoots when each leaf was tested at the base of the leaf sheath, at the base of the leaf blade and half way along the leaf blade. The rainfall in the interval between tests is also given.

Discussion

The results of the species survey (Table I) indicate that high nitrate contents do not often occur in the species tested. Out of a total of 26 species, 11 gave positive nitrate tests. More samples with high nitrate may have been found if a larger number of samples had been taken, but the results from the random samples which were tested indicates that in general the mixed herbage offered to livestock may not have a high nitrate content. This may not be true, however, if only a single species is offered.

The more detailed testing of *P. purpureum* shows that high nitrate contents can frequently occur in samples from this species. The pattern of occurrence is, however, difficult to define. The results show that there may be differences between strains, although this may be complicated by differences due to stage of growth. At all stages of growth the leaf sheath contained a greater concentration of nitrate than the leaf blade (Table III). There does not appear to be a definite correlation between height of growth and nitrate content, but after repeated showers of rain the nitrate content at all stages of growth tends to decrease.

In order to assess the quantities of nitrate in some of the shoots with high nitrate tests, a dilution method was used. An aqueous extract of material, dried rapidly under an infra-red lamp and weighed, was diluted until a single drop tested with diphenyl-amine solution indicated a nitrate concentration within the range 5-25 p.p.m. The results expressed in terms of potassium nitrate indicate that the high nitrate material used in the spot tests, could have from 1.3-3.5 per cent potassium nitrate in the dry matter.

These results show that quantitative tests should be carried out to assess the level of nitrate in *P. purpureum* herbage consumed by livestock. A potassium nitrate content of 1.25 per cent may cause reduction in milk yields (Mukrer, Garner, Pfander and O'Dell, 1956) and a content of 3.50 per cent could be lethal for a 500-lb. cow. (Whitehead and Moxon, 1952.)

Conclusions

The results from this preliminary survey show that the nitrate content of herbage from most grasses growing around the Animal Health Research Centre at Old Entebbe is rarely high. The exception is *Pennisetum purpureum*. Detailed quantitative studies on the nitrate content of herbage from this species should be undertaken.

References

Ferguson, W. S., and Terry, R. A. (1956). The effect of nitrogenous fertilizer on the non-protein fraction of grassland herbage. *J. Agric. Sci.*, *48*, 149.

Griffith, G. Ap., and Manning, H. L. (1949). A note on nitrate accumulation in a Uganda soil. *Trop. Agric.*, *26*, 108-110.

Mukrer, M. E., Garner, G. B., Pfander, W. H., and O'Dell, B. L. (1956). The effect of nitrate on reproduction and lactation. *J Anim. Sci.*, *15*, 1291-2.

Spurway, C. H. (1944). Soil testing. Michigan State College, A.E.S. Section of Soil Science Tech. Bull., 132.

Whitehead, E. I., and Moxon, A. L. (1952). Nitrate poisoning. S. Dakota A.E.S. Bull. No. 424.

TABLE I—A SUMMARY OF THE RESULTS OF NITRATE SPOT TESTS ON VARIOUS GRASS SPECIES

Species	Date of Test														
	13–3–58			15–3–58			17–3–58			1–12–58			23—24–11–59		
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*
Axonopus flexuosus							2	0	0				16	0	0
Brachiaria decumbens	2	0	0										22	0	0
Bothriochloa glabra				1	0	0							24	0	0
Cenchrus ciliaris	2	0	0										30	2	0
Chloris gayana	1	0	0	2	1	0	1	0	0	9	0	0	26	0	0
Cymbopogon afronardus				2	0	0							16	0	0
Cynodon dactylon	2	1	0	2	0	0	1	0	0				48	18	0
Digitaria decumbens	1	0	0												
Digitaria scalarum	1	0	0							6	0	0	22	7	1
Eleusine indica	2	1	0										27	12	5
Eragrostis mildbraedii				2	0	0							30	0	0
Eragrostis tenuifolia	1	1	0												
Hyparrhenia filipendula										2	0	0	10	0	0
Hyparrhenia rufa				1	0	0	1	0	0				36	0	0
Imperata cylindrica				1	0	0							12	0	0
Melinis minutiflora	1	0	0							9	0	0	29	4	0
Panicum maximum	2	1	0	1	0	0	1	0	0	2	0	0	18	0	0
Panicum trichocladum							1	0	0				27	3	0
Paspalum commersonii	1	0	0										17	0	0
Paspalum notatum	3	0	0	1	0	0				6	0	0	30	0	0
Pennisetum purpureum	2	2	2	2	2	1	3	2	0	3	1	0	(*see* Table III)		
Rhynchelytrum repens				1	0	0									
Setaria aequalis	2	1	0										16	10	1
Setaria sphacelata	1	0	0							6	0	0	33	0	0
Sorghum verticilliflorum				1	0	0									
Sporobolus pyramidalis				1	0	0	1	0	0				10	0	0

Note: a = No. of tests conducted.
b = No. of tests positive.
c = No. of tests with high nitrate (over 25 p.p.m.).

TABLE II—THE DISTRIBUTION OF NITRATE IN TWO SHOOTS OF *Pennisetum purpureum*

		DIVISION OF LEAF IN INCHES											
		Sheath			Blade								
		6–4	4–2	2–0	0–2	2–4	4–6	6–8	8–10	10–12	12–14	14–16	16–18
I	Outside leaf	3	1	0	0								
	2nd ,,	3	3	3	1	0	0	0	0				
	3rd ,,	3	3	3	3	2	2	1	0	0			
	4th ,,				3	3	3	3	1	1	0	0	
	5th ,,				1	1	1	2	2	0	0	0	
	6th ,,				0	1	2	3	2	0			
II	Outside leaf	0	0	0	0								
	2nd ,,	0	0	0	0	0							
	3rd ,,	0	0	0	0	0	0						
	4th ,,	3	3	2	1	0	0	0	0	0			
	5th ,,	3	3	3	1	0	0	0	0	0			
	6th ,,			3	2	1	0	0	0	0	0		
	7th ,,			1	1	3	2	2	2	2	0	0	0
	8th ,,				1	3	3	2	2	0	0	0	
	9th ,,				1	1	2	2	0				

Scoring: 0 No nitrate. 1 5 p.p.m. of NO_3.
10 p.p.m. of NO_3. 3 25 p.p.m. of NO_3 and over.

TABLE III—THE PERCENTAGES OF TESTS OF *Pennisetum purpureum* HERBAGE WITH HIGH NITRATE CONTENT

Date of test	*Stage of Growth of Shoot (inches in height)*															Rainfall since previous test
	Up to 14			18—26			30—40			45—60			Mature			
	a	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	*a*	*b*	*c*	
23–11–59	54·2	46·2	13·3	0·0	0·0	0·0	26·5	17·9	3·4	0·0	0·0	0·0	0·0	0·0	0·0	1·09*
26–11–59	64·3	51·8	0·0	77·8	33·3	7·7	54·5	47·1	0·0	—	—	—	0·0	0·0	0·0	1·20
30–11–59	72·7	35·7	7·1	100·0	66·6	50·0	85·7	55·5	0·0	—	—	—	0·0	0·0	0·0	1·85
6–12–59	—	—	—	100·0	69·2	53·8	100·0	100·0	75·0	52·8	52·5	17·6	94·1	52·2	0·0	0·20
14–12–59	100·0	57·1	21·4	91·7	50·0	0·0	—	—	—	33·3	23·5	5·8	0·0	0·0	0·0	0·45
21–12–59	90·9	42·3	11·7	—	—	—	0·0	0·0	0·0	93·3	76·2	5·0	35·3	19·0	0·0	0·06
28–12–59	61·5	46·1	0·0	0·0	0·0	0·0	100·0	60·0	0·0	76·5	42·8	0·0	0·0	0·0	0·0	0·13
4–1–60	9·1	7·1	0·0	80·0	25·0	0·0	—	—	—	82·3	13·0	0·0	0·0	0·0	0·0	Nil
12–1–60	0·0	0·0	0·0	—	—	—	89·5	26·6	0·0	100·0	100·0	40·0	25·0	18·2	0·0	2·06
18–1–60	0·0	0·0	0·0	0·0	0·0	0·0	—	—	—	18·8	14·3	0·0	100·0	42·9	0·0	0·20
25–1–60	54·5	26·6	0·0	94·1	71·4	0·0	0·0	0·0	0·0	47·1	0·0	0·0	—	—	—	1·24
1–2–60	80·0	50·0	28·6	100·0	85·7	80·9	100·0	88·0	64·0	100·0	56·5	13·0	0·0	0·0	0·0	1·08
8–2–60	0·0	0·0	0·0	0·0	0·0	0·0	—	—	—	0·0	0·0	0·0	38·8	0·0	0·0	0·79
15–2–60	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	57·1	36·0	0·0	2·86
22–2–60	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	0·0	1·67

a = base of sheath.

b = base of blade.

c = half way along blade.

* = previous seven days.

THE USE OF MOTORIZED KNAPSACK SPRAYERS FOR COFFEE PEST CONTROL IN UGANDA

By John Bowden, T. R. Jones and K. E. Woodcock, Research Division, Department of Agriculture, Uganda

(*Received for publication on 16th March, 1961*)

Methods of controlling *Antestiopsis* spp. in peasant-grown arabica coffee have been under examination in Uganda since 1952. At that date, in North Bugisu district little coffee was being produced, because of antestia attack, and many owners were abandoning their plots.

A trial was laid down in the 1952/53 season in an effort to find a suitable applicator and an effective insecticide. A variety of applicators, ranging from simple hand dusters to knapsack sprayers and a motorized duster, were tested over a three-month period in the Buginyanya area, together with a trial of pyrethrum and D.D.T., each of these insecticides being tested both as a dust and liquid concentrate formulation.

As the result of this work, and considerable discussion with chiefs, growers and co-operative societies, a system of control was established based upon individually owned applicators, using pyrethrum dust, since D.D.T. appeared to increase lacebug incidence, and was not recommended. The system proved effective, and built up to some 7,000 grower units before being abandoned in 1956/57. The main reasons for abandonment were the variable quality of the dust, its poor storage qualities, and ultimate complacency on the part of the growers.

The gradual cessation of control brought about another increase in pest damage, including lacebug (*Habrochila ghesquierei* Schout) and further attempts were made to introduce firmly based control measures for both pests. Because of the past attitude of growers, it was apparent that methods dependent upon individual farmers would probably repeat the earlier failure, and the Bugisu Coffee Union in 1957 attempted to establish a control for lacebug based upon teams of pneumatic knapsacks, using malathion as insecticide. The equipment selected was of inferior quality, so the scheme eventually failed.

In early 1958, a comparison trial of two types of hand operated knapsack sprayers, one hydraulic, the other pneumatic, was conducted in Ankole on an area of about 180 acres of old-established arabica. Even when organized as two teams each under the immediate supervision of a senior officer average numbers of trees sprayed per applicator day did not exceed 275 for the pneumatic and 250 for the hydraulic, at respective costs of Sh. 30/47 and Sh. 27/62 per acre, (600 tree equivalent) excluding costs of supervision. Although these costs were not unreasonable, it was apparent that a method capable of spraying a considerably increased number of trees per day, with at most a moderate increase in cost per acre, was an urgent necessity in view of the continuing severity of insect attack. In Bugisu the situation was rapidly deteriorating, and in Ankole many growers were planting non-susceptible robusta at the expense of arabica.

Examination of motorized knapsacks had begun in 1953, eight types having been examined between then and 1957; one of these had been sent to the Coffee Research Station, Ruiru, for comparison with a pneumatic knapsack. A body of opinion had built up that motorized knapsacks could not be used for coffee spraying, due, it was thought, to inability to survive rough field handling and the problems of organization and logistics.

The success of teams of motorized knapsacks in control of cocoa capsids in West Africa prompted a closer look at the field use of motorized knapsacks, since if they could be used, the problem of rapid coverage would be solved, and, on the basis of operating costs in the West Coast, it did not appear that such spraying would be over-expensive.

The machine finally chosen for further trial was the Motoblo 75, for the following reasons:—

1. It was of robust construction, requiring few modifications to withstand operation under local conditions.
2. It was of simple layout enabling easy access to all parts for maintenance.
3. It incorporated a recoil starter device which is considered essential for a two-stroke engine.

4. The engine could be relied upon to start hot or cold and operate efficiently at all altitudes encountered.
5. Constant rate of discharge when moving nozzle through a wide arc.
6. Simple, but effective, nozzle structure.
7. Good weight distribution, making it comfortable to carry.

Accordingly, trials were carried out at Sipi, Bugisu, in August, 1958, and at Fort Portal, in September, 1958. In the first of these a diffuser was used *in situ,* with a technique that was more or less drift spraying. The organization left much to be desired, and both insecticide dosage (again malathion was used) and gallonage per acre varied, the latter from 10 to 20 gallons. In the Fort Portal trial, closer supervision was exercised, and no diffuser plate was used. Combined with the machinery test, a comparison was made of three rates of malathion, at 1, 2 and 3 pints per acre. Assessment of the results of the trial, which was done on 9 acres of arabica, suggested that 2 pints per acre, in 13½ gallons of water per acre applied by a full, unrestricted air-blast would give an adequate control of antestia.

These conclusions were then tested in January, 1959, at Buginyanya, Bugisu, on 65 acres of arabica. Spraying staff were Bugisu Coffee Board instructors who were given training in operating the mistblower selected for the trial. At the same time, field officers of the district staff were used in supervisory capacities to familiarize them with organization of teams of machines and techniques of spraying.

Seven machines were used, and operated in two teams of three, with one spare machine. Adjacent blocks of coffee were sprayed in parallel from a common base, at which field maintenance, mixing of insecticide, stores, etc., were organized. The mixing base staff also decided plot to plot movement of teams according to a prearranged plot numbering and tree count chart.

The trial showed that team spraying of coffee, using motorized knapsacks, was a viable proposition. At 2 pints per acre (1,000 tree equivalent), applied in 18 gallons of water (for convenience these were assessed at appropriate rates per 100 trees, caluclated to the nearest 50) a 90.9 per cent reduction of antestia populations was achieved; no costings were taken, since the trial was confirmatory for techniques and exploratory for organization and logistics.

Following experience at Buginyanya it was decided to adopt team spraying based upon a motorized knapsack. It then became apparent that the two areas most in need of spraying required a somewhat different approach to the problem because of the very different distribution of the coffee. In Bugisu, coffee is grown on the slopes of Mount Elgon, some 22,000 acres being cultivated. Population is dense, and coffee plots, which average about ¼ acre, are close together and inextricably tangled with banana plots. The terrain is mountainous and broken with very few access roads. It was obvious, therefore, that apart from transport of stores to selected bases, spraying operations would have to be based upon a series of pedestrian teams.

In Ankole, by contrast, about 2,800 acres of arabica are grown in small but compact areas, mainly around the periphery of the district, the configuration of the land being more open and less precipitous than in Bugisu. The coffee areas vary between 20 and about 1,100 acres, with an average of about 280 acres. There are ten *sazas* (counties) involved, and to set up a series of independent spraying teams to cope with this scattered acreage would have been uneconomic. It was therefore decided to establish a fully self-contained, permanent, mobile spraying team, led by a senior officer, which would be responsible for the entire acreage of Ankole coffee.

The Bugisu organization was set up in early 1959. Since its inception the organization has been continuously modified and adapted in the light of experience, but has now settled down into a highly efficient organization, with the best teams capable of spraying 641 acres (each of about 1,000 trees) in a month of 23 working days, with a drastic reduction in costs.

A Bugisu spraying team now comprises an agricultural assistant in charge; one field mechanic; four supervisors for pest sampling, plot numbering and tree counting, mixing insecticide and for the supervision of spray application; a headman spray operator and two spray operators for each of ten working mistblowers; one recorder; 13 labourers whose duties include mixing and carrying insecticide, petrol and oil; carrying two or three spare machines and to assist the recorder in sampling and tree counting. Several day and night watchmen are employed when necessary. About 50-60 personnel are employed most of the time and all but the man in charge are paid only for days worked.

Pretreatment work includes pest sampling. For *Antestiopsis* a sequential method is used (Rennison, *in press*). Tree counting is carried out and each coffee plot is given a number and the owner's name, and number of trees, are recorded in a master list. With the aid of the master list and a knowledge of the locality, the supervisor in charge selects mixing points. Here the operators will be allocated plots to be sprayed and issued with requisite amount of insecticide. Plot owners are forewarned so that they may bring water to mixing points on the day of spraying in their area. For efficient operation of the team it is essential that adequate water is always at hand.

The team assembles at the first mixing point at 6.30 a.m. when the mistblowers are filled with insecticide and "petroil" and the engines started. For distant plots the machines are turned off, to be restarted on arrival, while for those nearby they are allowed to idle until spraying begins. The headmen and spray operators alternate as guides or sprayers and, when necessary, in bringing further supplies of insecticide from the mixing point. Rate of application is one tankful, i.e. 18 pints, to 150 trees, and operator change-over usually takes place after each tankful. Depending upon plot size, one to three machines may operate within a plot.

An operator walks between rows of trees, spraying alternately the tree immediately forward of him in each row, thereafter moving forward to the next pair. The operator works in alternate rows so that each tree is sprayed from one side only, the nozzle being held four feet from the nearest foliage. The spray is applied with a slow rotary movement of the nozzle, up or down the tree, to increase foliar disturbance and improve spray penetration. The nozzle used is a "straight through" venturi type with air-jacket, having no diffuser, and giving an airspeed at point of entry to foliage of approximately 35 m.p.h. at an adjusted liquid throughput of 20 g.p.h.

When the treatment to the area immediately around the mixing point is completed, the mixing personnel and equipment move on to the next point and work resumes from there. Sometimes, in order to maintain continuity, two mixing points are operated simultaneously.

Since malathion, which is of low mammalian toxicity, is the insecticide used, only mixing personnel wear protective clothing in the form of long rubber gloves. Soap is, however, issued to all personnel.

Field repairs which are limited to the fuel system, spark plug and other external fittings, are carried out during spraying operations by the field mechanic. A machine which breaks down is immediately exchanged for a spare machine, and checked. If the fault cannot easily be remedied the machine is returned to a base store for transmission to the Co-operative Union workshops. The field mechanic also carries out routine after-work servicing.

Machines and other equipment are stored in Co-operative Society stores or other suitable buildings, the owners of the latter being paid as temporary watchmen. Petrol and insecticide concentrate are kept in open storage, and all machines are drained of "petroil" prior to being placed in storage.

An integral and essential part of the general organization in Bugisu is the central workshop referred to earlier, which is maintained by the Bugisu Co-operative Union. It is staffed by two fully trained mechanics and deals with the more serious maintenance of all mistblowers in Bugisu, which now total over 100.

Table I includes the cost of spraying in Bugisu, based upon the work in November, 1960, of a team operating in Bulambuli district. It also shows comparative costs of the Ankole spraying scheme, reduced to a monthly average from the six-month period September, 1959, to February, 1960.

TABLE I—COSTINGS BUGISU/ANKOLE COFFEE SPRAY SCHEMES

	Bugisu (1)	Ankole (2)
	Sh.	*Sh.*
Wages	4,518/00	5,196/55
Travelling Allowances (staff)	416/10	770/72
Transport	84/00	322/13
Malathion	9,492/00	4,231/50
Petrol	1,003/68	432/92
Oil	251/10	116/47
Spares and Servicing Motoblos	405/00	126/69
Standing and Other Charges	515/92	1,638/98
TOTAL ..	16,685/80	12,835/96
Acreage	641·3 acres	254·6 acres
Cost/Acre	Sh. 26/02 (3)	Sh. 50/42 (3)

(1) Taken from work sheets of one team operating in November, 1960.

(2) Average monthly costing from work of Ankole team September, 1959—February, 1960 inclusive.

(3) These costs include the factor for European Field Officers salary, mileage and night allowance and 1/36 of the capital costs of the motoblos based on a 3-year depreciation.

A frequent criticism of motorized knapsacks is their high initial cost when compared with that of hyrdaulic or pneumatic types. A depreciation element is included in Table I, but Table II clearly demonstrates that in a comparison of capital costs per acre the motorized knapsack is far more economical.

TABLE II—COMPARATIVE CAPITAL COSTS OF VARIOUS MACHINES

Item	Leo Colibri No. 8s	Four Oaks Ross.	Motoblo 75	Motoblo 60
Purchase price	Sh. 450	Sh. 356/50	Sh. 1,500	Sh. 950
Expected life	years 3	years 3	years 3	years 3
Work capacity	acres 360	acres 360	acres 1,800	acres 1,800
Capital cost per acre	Sh. 1/25	cts. 99	cts. 84	cts. 53

It will be noted that there are considerable differences between the two teams in wages, travelling and transport, and standing and other charges. These arise from the fact that the Ankole team is a fully self-contained, mobile unit. The basic method of spraying is identical for both teams, except that one headman directs three mistblowers simultaneously, the spare operators following up to ensure that no tree is missed.

The mobility required of the unit for work in Ankole results in considerable differences in organization and structure between it and the unit in Bugisu. The Ankole unit is based upon seven mistblowers and is staffed as shown in Table III.

TABLE III—ORIGINAL STAFFING OF ANKOLE SPRAY UNIT

1	Field Officer-in-Charge.	
1	Supervisor/Mechanic.	
1	Mechanic Grade III.	
1	Supervisor	Mixing team.
1	Assistant	
3	Porters	
2	Team leaders	Personnel of 2 spray teams.
14	Spray operators	
1	Supervisor	Sampling team.
1	Assistant	
3	Porters	
3	Drivers.	
2	Camp boys.	
34		

The staff is supplied with a variety of tentage, carefully chosen to emphasize status and seniority. This was thought necessary in view of the need to maintain discipline in a mobile team operating under arduous conditions.

The unit camps centrally in each coffee area, the length of stay being dependent upon the acreage, transport between and within areas being provided by two three-ton lorries. These are specially constructed to carry up to 120 gallons of fuel for both vehicles and the spraying equipment, in addition to one month's supply of malathion concentrate, oil, ancillary equipment, tenatage and personnel.

A further consequence of mobility is that it is not possible to establish a base workshop, resulting in the need for comprehensive maintenance of mistblowers on site by a skilled mechanic. In the team structure, this mechanic because of the training required of him and the responsibility he carries, is also second-in-command. After 18 months operation, it is pleasing to record that the original seven machines are still in use. An important contributory factor in machine life is choice of a suitable two-stroke lubricant and fan bearing grease.

More recent experience, which has yet to be fully analysed, indicates that cost per acre in Ankole has been reduced to about Sh. 42. This has been achieved by dispensing with one petrol vehicle (which is now in use with a comparable team set up in Kigezi), leaving one diesel vehicle with lower maintenance costs, and reduction in insecticide costs. These modifications have carried with them an overall reduction in staff, which now totals 23 The introduction of sequential sampling (Rennison, *in press*) would still further reduce costs.

From results in Mitoma county, Ankole, spraying is considered to have doubled the yield of 1,000 acres of coffee, from 350 tons to 700 tons of Kiboko. This represents an increased revenue to the grower of about Sh. 550 per acre, and to Government of about £5,000 for an expenditure of approximately £2,500.

Accurate records are difficult to obtain in Bugisu. There are numerous teams spraying more coffee than co-operative societies admit to owning. The local grower tends to underestimate his coffee holdings to avoid taxation, and there is thought to be illicit transfer of coffee from one society to another. Until reliable data are available on coffee holdings and production it will be difficult to provide unequivocal proof of increases from spraying

in Bugisu, but it is clear that in many sprayed areas coffee is now being produced where formerly there was little or no crop.

The experience gained in operating these spray teams has shown that there are several essential features common to both mobile and locally based teams. These are:—

1. The choice of a sturdy, easily maintained motorized knapsack.
2. The restriction of running repairs to tightening up nuts, and cleaning plugs and carburettor filters.
3. The provision of adequate repair facilities, staffed by trained mechanics, whether at a base workshop or with mobile teams.
4. The standardization of tools, equipment and method.
5. Local manufacture of certain essential tools, not commercially available, without which maintenance becomes practically impossible.
6. The use of minimum volume of liquid.
7. The supply of water by the grower.
8. A high level of supervision at all stages.
9. Efficient supply lines to cope with the fast movements of spraying teams.

SUMMARY

A brief account is given of the development of mechanized spraying of arabica coffee in Uganda.

The operation of teams of sprayers using motorized knapsack mistblowers is described. In Bugisu district a number of pedestrian teams are necessary to deal with dense coffee in difficult terrain, whereas in Ankole district a self-contained mobile unit has been developed to spray a relatively small acreage of coffee scattered over a large area.

Costs are shown to be about Sh. 26 per acre in Bugisu, and Sh. 50 in Ankole, although improvements in the latter district have reduced costs to about Sh. 42 per acre.

A summary of certain essential features of the organization of spraying teams is given.

ACKNOWLEDGEMENTS

The success of the spraying operations described is due in no small measure to the enthusiastic support of district staff of this Department, in particular Messrs. E. W. King, C. D. Watkins and I. Gedye. This paper is published with the permission of the Director of Agriculture.

REFERENCE

Rennison, B. D. A method of sampling *Antestiopsis* in arabica coffee in chemical control schemes. *E. Afr. agric. for J.* in the press.

ABSTRACT

PIENAAR, D. V. DE. V. (1960). 'N Uitbraak van Miltsiekte onder Wild in die Nasionale Krugerwildtuin 28.9.50 tot 20.11.59. *Koedoe*, No. 3, 238-251.

Unfortunately there is only a short summary in English of this important paper which is published in Afrikaans. The onset and course of an anthrax epidemic amongst game animals in the Kruger National Park are described. The most important sources of infection were the watering points and carnivorous birds and carrion eaters helped to spread the disease. Fire was successful in controlling the disease.

The species affected included kudu (*Tragelaphus strepsiceros*), water-buck (*Kobus ellipsiprymnus*), tsessebe (*Damaliscus lunatus*), buffalo (*Syncerus caffer*), roan antelope (*Hippotragus equinus*), hippopotamus (*Hippopotamus amphibius*), cheetah (*Acinonyx jubatus*) and civet cat (*Viverra civetta*).

G. R. S.

TRICHILIA ROKA FORSKAL (T. EMETICA VAHL.)

By R. Child

(*Reecived for publication on 12th April, 1960*)

The genus *Trichilia* L. of the family *Meliaceae* is a large one of trees and shrubs According to Staner and Gilbert [1] there are 240 species pantropical, chiefly in America; about 57 African species, of which 12 are described from the Belgian Congo. Brenan and Greenway [2] list eight species in Tanganyika, and for Uganda Eggeling and Dale [3] give eight.

Distribution

Trichilia roka (Forskal) Chiovenda (Fl. Somala 1932, II, p.131) (Syn. *T. emetica* Vahl., (Symb. Bot., 1790, I, p.34)) is widely distributed in Africa; it is found particularly in Mozambique; in the islands of Madagascar and Réunion; and at about an equal distance north of the Equator in the Sudan and Ethiopia. It is widespread throughout Tanganyika, usually on heavy soils, in riverain and alluvial forests. In Kenya it is fairly common in the warmer parts of the country where there is good rainfall; it is met with on the coast, in the lower montane rain forest on Mount Kasigau and the Kitui hills at 4,000 to 5,000 ft., and in the semi-tropical Rain Forest on east Mount Kenya, and in the Lake Victoria basin (Kakamega) at 4,000-5,500 ft. (Battiscombe [4], Wimbush [5].) According to Eggeling and Dale, two distinct forms occur in Uganda, one a small erect tree in savanna lands subject to grass fires away from water, the other a much larger spreading tree on river banks or lines of seepage. In Nyasaland it is common at lake levels; very abundant at Karonga (Lake littoral). It is recorded in Southern Rhodesia from Victoria Falls; Wankie; Chipinga; Sabi Valley. In Northern Rhodesia it is general.

Description

It is a large handsome tree with a spreading crown and dark green leaves; usually 15 to 40 ft. high, it may attain a height of 70 ft. or more. The bark is smooth and pale grey to brown; the blaze (woodman's mark by chipping into the bark and wood) is creamy-white below the cork layer, turning reddish brown. The leaves are up to 18 in. long, made up of seven to eleven leaflets, 2½ to 6 in. long. The flowers (yellowish white) are produced in clusters at the axils of the leaves. The fruit is a capsule containing the seeds (1 to 3) which are about ¾ in. long by ½ in. broad; they are dark brown and are covered with a red aril. Reference may be made to the authors quoted in the introduction for further systematic description.

Popular and Vernacular Names

Portuguese East Africa.—The commonest name given to *T. roka* is Mafura, and it is by this that it has been known commercially. Varieties of the name are *Mafurreira, Malfura, Mafurra, Mafoura.* Local names in Mozambique are *Mutukuri, Moreka* and *Mutumbe* in Quelimane, and *Umkubu, Nkusu, Tunhlu, Unchcho, Kuhlu* and *Esschenhout* in other parts of the country. (Guardado [6].) Daniel and McCrae from information given by the Medical Officer of the Witwatersrand Native Labour Association in 1908, examined samples of oil and fat prepared by natives in Portuguese East Africa, and quote the following names: *Umkuhlu, Mkhuklu, Marba, Marwa-Maawa, Gnanda,* as well as *Mafura.*

South Africa.—The name *essenhaut* comes from South Africa (*Rooi-essenhaut*); the tree is also called *Natal mahogany.*

Belgian Congo.—*Mbimbi* (Kilumbwe dialect); *Mukeka* (Kilia dialect); *Mushikinshi, Shikinshi* (Lukafu).

Uganda.—Eggeling and Dale give *Makaku* (Lunyoro, Bugungu dialect); *Okofe* (Lugbara); *Achilo* (Madi); *Aming* (Luo A.); *Akwirakwir* (Luo L.); *Kichombe* (Lugishu).

Kenya.—*Mtimaji* (Swahili-coast); *mkungwina, mnwamaji* (Swahili); *mutwati, mururi* (Kikuyu); *mutwati* (Meru); *mudimadi* (Digo); *Ivojo* (Kakamega).

Rhodesia.—The Mashona names are given as *mu-Chenya* and *mu-Chichiri* [8]. Other vernacular names in the Federation are given by Palgrave [13]; mostly variants of *muSikili* (the Si-Lozi name).

The tree has also been referred to as the *tallow tree,* and as *Ethiopian mahogany.*

Most of the literature relating to the chemistry of the oil uses the botanical name *Trichilia emetica* Vahl. Some older literature refers to *Mafureira oleifera* Bert.

USES

Timber.—Wimbush [5] gives the following details; Heartwood pale pinkish brown merging into yellow sapwood, of medium to rather coarse texture, generally straight-grained, but with occasional wavy grain figure, light to medium weight (32-36 lb. per cubic ft. air-dry), soft but firm and easy to work, takes nails well, and easy to polish. It is susceptible to blue-stain due to mould when freshly sawn and also to wood-borers. It is used for joinery and furniture.

Medicinal.—There is little information on the medical uses. Gethins [9] refers in very general terms to the use of extracts of bark or leaves as tannin-containing astringents, used in dysentery. Brenan and Greenway state that a boiled extract of roots is drunk as anthelmintic. The origin of the former specific name *emitica* must presumably relate to some medical use. Palgrave [13] states that the Zulus use an infusion of the bark as a purgative enema, producing sweating and vomiting. A hot infusion of the leaf is used as a lotion for bruises, and leaves placed in one's bed at night are claimed to induce sleep.

Oil ("tallow").—Mafura seeds have a thin fragile shell and a red skin or aril. Two fats of somewhat different properties are obtained respectively from the kernels and from the shell plus aril.

The writer in 1954 had the opportunity of examining seed of *T. roka* collected in Southern Tanganyika in the district between Tukyu and Mwaya on Lake Nyasa. The seeds were being crushed for oil and the latter used in soap making by a small factory at Kyela. A good tree can give in the season up to 60 lb. dry seeds.

The results of the examination of the seeds, oil and press cake are here reported and compared with information from the literature.

The seeds had an average weight of 0.50 gm., of which 70.6 per cent represented kernels, and 29.4 per cent shell plus aril. This accords well with the seeds from the Sudan examined by Henry and Grindley [10], which had an average weight of 0.52 gm., with 72.6 per cent of kernel and 27.4 per cent shell plus aril.

Extraction of the materials with petroleum ether gave two fats with the following characteristics (literature figures for comparison).

	Present work	Ref. 10	Ref. 11	Ref. 12	Present work	Ref. 10	Ref. 11	Ref. 12
Fat % in material ..	54·3	61·8	55–65	+60	44·7	53·5	35–40	25–35
Characteristics of Fat:								
Saponification Value	204·2	198	198–201	—	206·8	199	195–202	202·5
Iodine Value ..	43·5	42·1	43–59	—	50·0	71·8	66–72	66

Other chemical characteristics are given in the references quoted. The commercially pressed oil from the small factory had a very high acid value equivalent to 23.3 per cent of oleic acid. Rindl [12] mentions the high acid value of the kernel oil. It is used for soap-making, but could not be economically refined for edible purposes.

Guardado [6] gives figures of exports of mafura seed, oil and press cake from Mozambique for the years 1911-1928; the amounts fluctuated considerably, in some years being as much as 5,000 metric tons of seed, and 200 tons of oil.

There seems to be lacking any more recent information about the current production of Mafura "tallow" and any uses to which it may be put.

Press Cake.—Samples of press cake from Tukuyu had a nitrogen content of 2.6 to 2.8 per cent, so had a limited manurial value. Laboratory samples of the extracted arils, fat free and dry, had N 2.4 per cent; kernels, fat free dry residue, 4.79 per cent.

Bitter Principles.—Like the fats of some other *Meliaceae* spp. (e.g. Margosa oil), the seeds and the fat extracted therefrom contain a bitter, non-nitrogenous unsaturated fraction. Henry and Grindley give some particulars of this, but there appears to be no later information. The bitter principle of Margosa oil has

been much studied by Indian workers, and that of *T. roka* would present points of chemical interest.

Conclusion

A review is given of the distribution of *Trichilia roka* Forskal and of its potential uses, with particular reference to "Mafura tallow". Although at one time considerable quantities of this fat were exported from Mozambique, any commercial exploitation in British East Africa seems likely to be local, as with the small Tanganyika business mentioned. Wimbush describes the frequency of occurrence of the tree as "occasional or rare", and it is understood that in Kenya saw-millers make little use of it, as it does not occur in economic "stands".

Acknowledgement

I am indebted to Mr. O. Kerfoot, of E.A.A.F.R.O., for information particularly relating to Nyasaland and Northern Rhodesia.

References

[1] P. Staner and G. Gilbert. *Meliaceae* in "Flora du Congo Belge et du Ruanda-Urundi. Spermotophytes, Volume VII". (Brussels, 1958), pages 163-164.

[2] J. P. M. Brenan and P. J. Greenway. "Check Lists of the Forest Trees and Shrubs of the British Empire No. 5. Tanganyika Territory, Part II". Oxford, 1949, p. 318.

[3] W. J. Eggeling and I. R. Dale. "The Indigenous Trees of the Uganda Protectorate." Second Edition, 1951, pp. 195-196, *ill.*

[4] E. Battiscombe. "A Descriptive Catalogue of Some of the Common Trees and Woody Plants of Kenya Colony." 1926, p. 82.

[5] S. H. Wimbush. "Catalogue of Kenya Timbers." Nairobi, 1950, p. 67.

[6] Raúl A. da Silva Guardado. "A Mafurreira (*Trichilia emetica* Vahl.)." *Bol. agricola e pecuario* (Moçambique), 1930, Nos. 1 and 2, pp. 43-49.

[7] W. R. Daniel and J. McCrae. "Mufura Tallow and Mafura Oil." *Analyst*, 1908, *33*, 276-277.

[8] "Vernacular-Botanical Names of Some Trees and Shrubs in Mashonaland." *Rhodesia Agric J.*, 1953, *50*, p. 156.

[9] T. S. Githens. "Drug Plants of Africa." 1948, pp. 7, 50, 60, 107.

[10] A. J. Henry and D. N. Grindley. "The Oils of the seeds of . . . and *Trichilia emetica*." *J. Soc. Chem. Ind., Trans.*, 1944, *63*, 188-190.

[11] E. W. Eckey. "Vegetable Fats and Oils." Reinhold, U.S.A., 1954, pp. 560-561.

[12] M. Rindl. "Mafurra Tallow, a Product of the Nuts of *Trichilia emetica*," *South Africa J. Ind.*, 1922, *5*, 415-423; *J. Chem. Soc.*, 1922, *122* (i), *Abstr.* 1102.

[13] K. C. Palgrave. "Trees of Central Africa." (National Publications Trust of Rhodesia and Nyasaland, Salisbury, 1956).

ERRATA

(*E. Afr. agri. for J., Vol. XXVII—No.* 1 (*July*, 1961))

Page 44, line 3, *for* 50 per cent *read* 58 per cent.

Page 44, *for* paragraph 2 *read*:—

> "The weight of lean meat in the carcass expressed as a percentage of an animal's liveweight which according to Dr. Callow is approximately 32 per cent and varies little among breeds of cattle is 33 per cent in the Zebu at Muguga and 31 per cent in the goat at Mpwapwa, Tanganyika. At Muguga, however, Wildebeest carcasses averaged 42 per cent lean meat while Thomson's Gazelle averaged 46 per cent. Several pages of detailed data were presented as an appendix to this paper. The game species were thus shown to produce more lean meat and less fat than do domestic cattle."

THE RATIONAL EXPLOITATION OF THE *Tilapia esculenta* STOCK OF THE NORTH BUVUMA ISLAND AREA, LAKE VICTORIA

By D. J. Garrod, East African Freshwater Fisheries Research Organization, Jinja, Uganda

(*Received for publication on 10th April, 1961*)

It is a well-established feature of biological systems that the constituent organisms are in balance with each other. This is true of a fish population which is in balance with the other organisms of its own ecosystem, and within itself in so far as the numbers of fish entering a fish stock are approximately equal to those dying by natural causes.

It is also true that, as fish grow through the population, they reach a particular size where the increase in weight in a year, due to the growth of all the fish in the population of that size, is balanced by the loss of weight due to natural death. The maximum yield of a fishery could thus be obtained by removing all fish as they reach this age. In practice it would require an infinite amount of fishing to accomplish this, and it is general practice in fishery management to begin cropping fish just before they reach this ideal size and age.

As soon as fishing begins the numbers of fish in the population at any one time are reduced but, as in other biological systems, the population adapts itself to this new mortality factor, and a new equilibrium balance develops at a different level from that obtaining when there was no fishing. This balance is controlled by the relationship between the rate of growth of the fish, the rate at which new fish enter the fishery as a result of breeding (recruitment), and the factors causing mortality. The control exerted by the degree of fishing mortality is of overriding importance because the growth rate and recruitment tend to adjust themselves to it, to restore the *status quo*. A fishery is, therefore, capable of existing at an infinite number of equilibrium levels which can be controlled by the manipulation of the fishing effort.

However, although the equilibrium levels can exist, the crop of fish that can be taken at different levels will vary, and there is only one level which will give a maximum yield either by weight or numbers.

As soon as fishing begins, the density of the population declines and the catch per unit fishing effort (catch per net) will also decline so that it is possible for the level of fishing which returns the maximum catch, to return an uneconomically low catch per net. In this case fishermen will cease to operate before the fishery is yielding its overall maximum and economic overfishing is said to occur.

On the other hand, the number of eggs and fry produced by a population is related to the weight of the population (biomass), and as fishing increases the number of eggs spawned is reduced. Within certain limits the percentage survival of these eggs increases as the population declines, thus maintaining recruitment to the population at the former level despite the fewer eggs produced. Nevertheless, a degree of depletion of the population can be achieved where the increasing proportional survival of eggs reaches its limit and cannot maintain the rate of recruitment that obtained in the original stock. In this event a biological decline, over and above that caused by fishing, will occur in the stock. This is biological overfishing.

It is an objective of fishery research to analyse the population dynamics of a species in order to reach a compromise between these three separate levels, where the maximum catch is obtained without causing either economic or biological overfishing.

An investigation of this type is carried out by estimating the parameters controlling population size, the growth rate, natural mortality and the relationship between fishing effort and the fishing mortality that it exerts, and the recruitment rate. These are then incorporated into a mathematical model of the fishery.

The size selection characteristics of the fishing gear must also be taken into consideration because, for example, $4\frac{1}{2}$-in. mesh gill nets catch smaller fish than 5-in. nets and it is necessary to know whether increased numbers of fish caught in $4\frac{1}{2}$-in. meshes can offset the lower weight per fish.

An investigation on these lines has recently been carried out on the *Tilapia esculenta* stocks of the North Buvuma Island area of

Lake Victoria. The mathematical model applicable to a gill net fishery such as this, was developed by Beverton (1959). In most fisheries the population structure of any one species is normally determined by tracing the survival of a given number of fish from the time that they enter the fishable stock until they have all died under the combined influence of fishing and natural mortality. This may be done for successive age classes, but for *T. esculenta,* which demonstrates a considerable range of length for a given age, it is more informative to consider the survival of fish through successive length classes.

The Model

Consider a number of fish of length group x, (Nx). These may be subject to a degree of natural mortality, Mx, and a proportion of the fishing mortality, Fyx, which is related to the maximum efficiency F of the gear at the mode of the mesh selection range. If the time required to grow through the length group is tx then the number of fish surviving to the next length group, x + 1, is given by—

$$N_{x+1} = N_x \, e^{-(Fyx + Mx)tx} \quad (1)$$

In practice it is not possible to estimate accurately this instantaneous abundance and it is usual to determine the population structure at any one time by an equivalent measure, the average abundance, which is obtained by integration of expression (1) for all lengths between x and x + 1.

If this average of abundance is given by $\bar{N}x$ then the average abundance is—

$$\vec{N}_x = \frac{N_x}{Fyx + Mx} \left(1 - e^{-(Fyx + Mx)tx}\right) \quad (2)$$

Now if 1,000 fish are recruited at 23.0-23.9 cm. the application of expressions (1) and (2) will give the average abundance of this length group at any time together with the number of fish surviving to 24.0 cm.

These calculations are repeated for successive length groups until the 1,000 recruits have disappeared. If the mortality factors remain constant the population will be in equilibrium with a structure given by the average abundance of each length group. Any change in these parameters will destroy the equilibrium but the evidence of a *sustained* yield implies stability and transitional states are not considered except to note that, if mortality does change, the fishery will not re-establish a new equilibrium until all the fish in the population have been subject to the same level of exploitation throughout their exploited life history, i.e. until the fish recruited at the time of the change have disappeared from the fishery.

The average abundance figures represent the population available to the fishery at any one time. The biomass of the population is the product of the abundance and the average weight of a length group summed for all length groups. The catch is the average abundance multiplied by the relevant fishing mortality in each length group and the weight yield the product of the numerical yield and average weight as before. The catch per unit effort is the yield divided by the fishing mortality since F is proportional to the fishing effort (*see* below).

The Estimation of the Parameters Controlling Population Size

(i) *Growth Rate.*—The relevant values of t for each length group are calculated from the growth rate which has been previously determined (Garrod, 1959). In this work it was shown that the growth rate of *T. esculenta* in the exploited phase of the life history could be fitted by von Bertalanffy's equation of growth (*see* Beverton and Holt, 1954). From the expression—

$$L_{x+1} = L\infty - (L\infty - L_x)e^{-Ktx}$$

where L_x, L_{x+1} are successive length groups,

$L\infty$ is the asymptotic length towards which the fish are growing,

K is a constant defining the rate of deceleration of growth,

t is the time interval L_x to L_{x+1},

$$t_x = -\frac{1}{K}\log_e \left\{\frac{L\infty - L_{x+1}}{L\infty - L_x}\right\}$$

For this particular stock of *T. esculenta* $L\infty$ = 36·5 cm. and K = 0·28.

(ii) *Fishing Mortality.*—The relationship between fishing effort (gill net nights per month) and fishing mortality has been defined by tracing the survival of given age classes of *T. esculenta* through five seasons during which substantial fluctuation of fishing effort occurred (Garrod, in press). The relationship is illustrated in Figure I. Arithmetic increases in effort give arithmetic increases in the fishing mortality which is expressed as an exponential

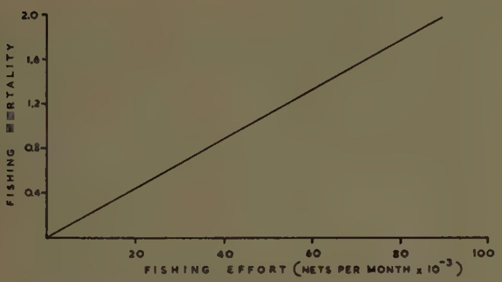

Fig. I.—The relationship between fishing effort and the fishing mortality that it exerts

coefficient, but this does not bear a direct relationship to the percentage removal. Clearly it is not possible to remove 100 per cent of the population by gill net fishing and representative comparisons between the coefficient of mortality and the percentage mortality are given below:—

Mortality coefficient	*Percentage mortality*
0.25	20
0.75	50
1.50	80

The fishing mortality coefficients quoted in the text refer to the mortality at the length groups for which the gear is most efficient. Gill nets are extremely selective and length frequency distributions of the catches are approximately normally distributed about a mode of peak efficiency. The shape of the curve has been defined (Garrod, 1961) and, for example, $4\frac{1}{2}$-in. nylon gill nets have a mean retention length at 29.3 cm. with a standard deviation of 1.48 cm. The fishing mortality at any length group (Fyx) is referred from the maximum mortality operating at the mean retention length by an arithmetic factor given by the selection curve.

(iii) *The Natural Mortality*.—The calculation of the two components of total mortality is carried out by an initial estimate of the total mortality which can then be subdivided using a knowledge of the relationship between the total mortality and fishing effort, and the selectivity of the gear, *see* (ii) above. The natural mortality is obtained by subtracting the fishing mortality from the total mortality.

The details of these four factors are given in Table I where they are relevant to the model of this *T. esculenta* population.

(iv) *The Rate of Recruitment*.—It has not been possible to estimate the variations of recruitment and in all calculations it has been assumed to remain constant regardless of the decreases in egg production that occur as soon as fishing begins. If biological overfishing is to be avoided the rate of recruitment must be maintained at the level obtaining in an unfished population; this may be achieved by density dependent increases in the proportion of eggs surviving and some relevant comments are made in connexion with the level of increase in survival that must be achieved in this *T. esculenta* fishery.

An analysis of this form is carried out by examining the reaction of a given number of recruits to different levels of fishing mortality exerted with gill nets of varied mesh size. The model can be used to predict the weight (biomass) of the population at any one time, the numerical and weight yields that may be obtained from it together with the variations in catch per unit effort. This information is expressed in arbitrary units, which bear an unknown relation to the natural population, but changes in the fishing mortality will induce the same *proportional* changes in the units of the model as will occur in the natural population.

The results of this analysis are abstracted below to give a rational explanation of recent trends in the North Buvuma Island *T. esculenta* fishery and to suggest how fishing may be improved. This is particularly important because the restrictions controlling fishing were removed in Uganda and Tanganyika in 1957, and in Kenya in 1961, with the result that, after a brief increase in yield of *T. esculenta*, the fisheries have declined very severely. At present it is no longer an economic proposition for African fishermen to work many of the inshore areas which were formerly the richest areas of Lake Victoria (Garrod, 1960).

The important information is given in the illustrations:—

Fig. II shows changes in the weight of the standing crop of fish.

Fig. III shows changes in the numbers of fish caught.

Fig. IV shows changes in the weight yield.

Fig. V shows the variation of the catch per net with increasing levels of fishing mortality.

Briefly, it can be seen that with all mesh sizes, the weight of the standing crop decreases with increased fishing, and that the effects are greater with smaller mesh sizes because they crop fish at smaller sizes.

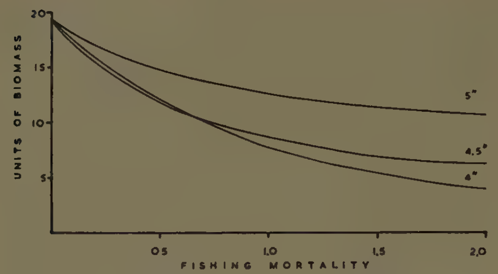

Fig. II.—Variations in the biomass of the population at different levels of fishing effort

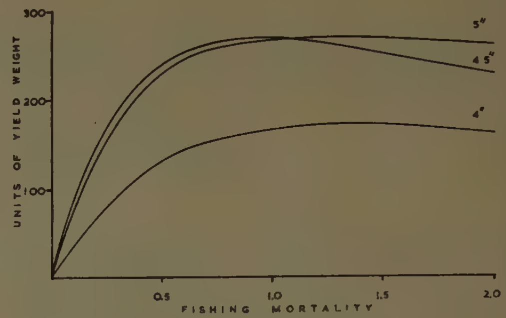

Fig. IV.—Variations in the weight yield at different levels of fishing mortality

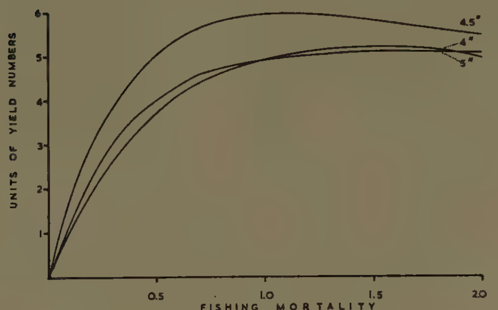

Fig. III.—Variations in the numerical yield at different levels of fishing mortality

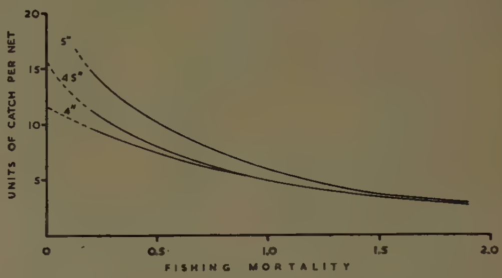

Fig. V.—Variations in the catch per net at different levels of fishing mortality

The numbers of fish caught are greatest with 4½-in. nets, but the numerical yield from 5-in. and 4-in. nets is comparable. On the other hand the weight yield from 4-in. nets is very inferior, but that of 4½-in. and 5-in. nets is similar.

It can be seen from Fig. IV that with 4½-in. nets the weight yield is maximum at about F = 1.0. Above this level the standing crop is reduced so much that it cannot support the catch given by a lower fishing effort on a higher standing crop.

The catch per net (Fig. V) declines progressively more slowly as fishing increases.

The application of this fact can be exemplified by a fishery which is fished at the level F = 1.0 corresponding to 46,000 nets per month. If the effort is increased to F = 2.0 (92,000 nets), the catch per net will decline slightly, but the yield will not be increased and the standing crop will be severely depleted, increasing the risk of biological overfishing with absolutely no benefit to the industry.

The findings of the model can be compared to the observed trends indicated by the fish landings at Masese, Jinja, since 1953. Between 1953 and the end of 1956 the fishery was fairly steady, giving a uniform yield of 22,000 fish per month from a fishing effort of 15,300 5-in. nets per month, i.e. F = 0.3.

Supposing the fishery to be in equilibrium, the model shows that the numerical strength of the standing crop was at that time 3,156,200 adult *T. esculenta*, weighing 1,529 tons, and giving a marginally profitable catch per net of 1.44.

During 1955/56, either as a result of poor recruitment or slightly increased fishing, the catch per net dropped and became uneconomically low, causing fishermen to try using smaller mesh sizes. These were found to give better catch per net yields because the smaller meshes caught fish from a section of the population which had never previously been exploited.

Consequently, in a very short space of time 4½-in. nets replaced 5-in. nets and the Government, taking a negative approach, repealed the unenforceable legislation.

These smaller meshes were fishing a standing stock built up under conditions of 5-in. net fishing (*see* Fig. II) and the model predicts that, at the fishing intensity of F = 1.0 which

prevailed for a short initial period, the rate of yield with 4½-in. nets from a standing crop of 3,156,200 fish would be 1,058,376 fish weighing 567 tons per year with a catch per net of 1.8 fish. The commercial statistics agree very closely and gave an average yield of 1,116,000 fish weighing 598.7 tons per year with a catch per net of 2.0.

The increased catch per net over that obtaining in the period 1953-56 demonstrates the incentive to increased fishing.

But this level of fishing destroyed the existing equilibrium in this fishery and the model shows that, had fishing continued at F = 1.0 for a sufficiently long period to establish a new balance, the standing crop would have declined by 38 per cent and the catch per net by 52 per cent. This decline of the latter was obviously unacceptable and as soon as it began, fishing effort readjusted itself to maintain a marginally profitable level. At present fishing effort is exerting a mortality F = 0.6 which the model predicts should yield 459,000 fish per year, weighing 236.8 tons. This may be compared to the actual yield of 438,000 fish weighing 236.4 tons. The catch per net stands at 1.36, very close to that obtaining prior to the mesh change. The numerical strength of the standing crop is 2,363,000 weighing 1,040 tons. This is 25 per cent less than in the 1953-56 period.

The accuracy of the above comparisons cannot be disputed and indicate the reliability of the predictions taken from the model. The maximum sustained yield that could be obtained from this area is approximately 272 tons per year when F = 1.0.

It is unfortunate that in 1957 an F.A.O. "expert" visited Masese for two or three days and then produced an estimate of a sustained yield of 1,800 tons per year, 75 per cent of which would be *T. esculenta.* Despite warnings from E.A.F.F.R.O. this grossly erroneous estimate was used to support the expenditure of several thousands of pounds at Masese on a market which now threatens to be a "white elephant" because of the poor fish catches.

The predictions that are outlined above are based on the assumption that fishing is carried out entirely with 4-in., 4½-in. or 5-in. meshes, but it is possible to investigate the effects of fishing fleets of nets of mixed mesh sizes by the same method.

The conclusions to be drawn are illustrated in Fig. VI and Fig. VII, which show isopleth diagrams of the numerical and weight yield for varying proportions of 4½-in. and 5-in. nets at constant levels of fishing mortality. These show that even with mixed mesh sizes the maximum yield is obtained at levels of fishing mortality F = 1.0, but that slightly greater yields are obtained by using 30 per cent 4½-in. nets and 70 per cent 5-in. nets than when the fleets are composed entirely of 4½-in. or 5-in. nets.

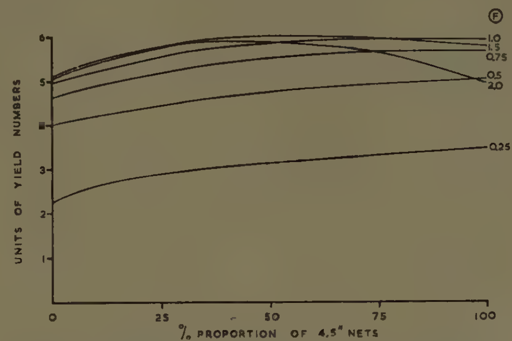

Fig. VI.—Isopleth diagram of the numerical yield against the proportion of 4½-inch nets in use, at given levels of fishing mortality.

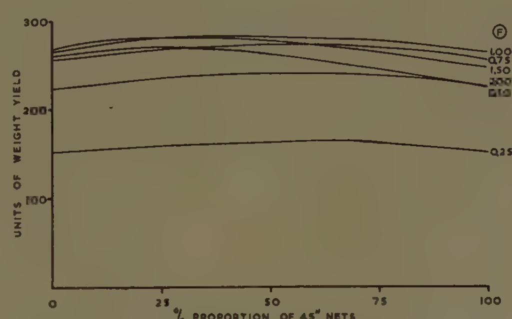

Fig. VII.—Isopleth diagram of the weight yield against the proportion of 4½-inch nets in use, at given levels of fishing mortality

This defines the maximum yield which can be cropped from the North Buvuma Island stock assuming that the rate of recruitment is maintained regardless of the depletion of the standing crop of adult fish, and its consequent implication for egg production.

It has already been pointed out that increasing levels of fishing mortality deplete the standing crop of the population and so decrease the egg production, and also that, if egg production falls below a given level, recruitment may decline.

By a process analagous to that described above for the estimation of potential yield, it has been determined that the North Buvuma

T. esculenta stock required a recruitment rate of approximately 860,000 adult fish per year. From the estimated egg production of the virgin stock this would require a 0.02 per cent rate of survival of fry, i.e. 2 in 10,000. Between 1953 and 1956 at $F = 0.3$ with 5-in. nets an increase in survival to 2.4 fish per 10,000 was necessary. The stability of the fishery at that time suggests that this increase was possible, but at $F = 0.6$ with 4½-in. nets (the present fishing rate) a survival of 4 in 10,000 is required if the fishery is to be stable.

This represents a 100 per cent increase in the proportion of fry surviving over that required by the unexploited stock and may well lie beyond its biological limit.

Reference to the estimates of yield compared with the actual yield showed an underestimate of 5 per cent in 1956 and an overestimate of 6 per cent in 1960. These errors lie in opposite directions and represent the effect to be expected if recruitment has not been maintained and biological overfishing has occurred. The errors are not of the type expected from an inaccurate model. It should also be noted that in many areas of Lake Victoria fishing effort declined in 1958 owing to economic overfishing, but there has not yet been any sign of a recovery. This again is indicative of biological overfishing: simple economic overfishing would have been followed by a rapid recovery of the fishery as soon as the fishing effort declined.

This evidence is not adequate to show that biological overfishing has occurred in the North Buvuma Island stock, but these are clear indications that the reduction of the standing crop at the present level of fishing has caused the rate of recruitment to become marginal and any change in fishing practice that will relieve this risk should be encouraged.

It has been stated that egg production is related to the weight, or biomass, of the standing crop of adult *T. esculenta*. The present biomass of the stock is 1,040 tons and it is suggested that a safe limit for recruitment, beyond which the stock should not be depleted lies at 1,100 tons. Fig. VIII shows the relationship between biomass and the yield for various proportions of 4½-in. nets at different levels of F. These show clearly that depletion of the biomass below 1,000 tons results in a decreased yield irrespective of its implication for recruitment. The maximum yield at biomass 1,100 tons is obtained with 25 per cent 4½-in. and 75 per cent 5-in. nets at $F = 1.0$.

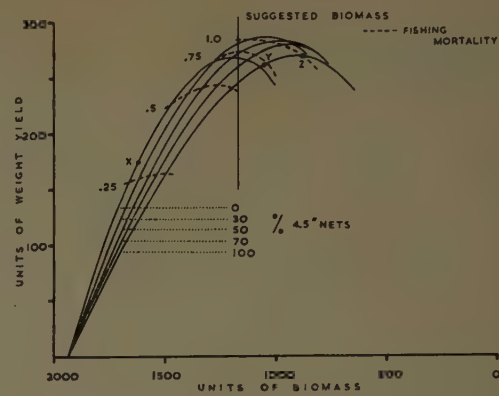

Fig. VIII.—Variations of weight yield and biomass with given proportions of 4½-inch nets in use.

X.—Equilibrium level of fishing with 5-inch nets, 1953-1956

Y.—Equilibrium level that will develop if the present level of fishing is continued (F = 0.6 with 4½-inch nets) and biological overfishing does not cause a decline in yield.

Z.—Equilibrium level that would have developed if the fishing effort of 1956/57 had been maintained.

This then is the most rational method of exploiting this particular stock of *T. esculenta*. The area of the habitat has been estimated at 29,235 acres, so that the body of water could yield 20 lb. per acre per year from a standing crop of 84 lb. per acre adult *T. esculenta* when exploited with an average number of 0.4 4½-in. nets and 1.2 5-in. nets per acre per month. This is within the normal range of yield of natural fisheries.

At present with 4½-in. nets being fished at 0.9 nets per acre per month, the fishery is yielding 18.2 lb. per acre per year from a standing crop of 79.7 lb. per acre.

The present method of fishing is not returning the optimum catch, but it has decreased the standing crop to a marginal safety level. If 4½-in. mesh fishing continues the fishing effort should be reduced to 0.75 nets per acre per month to preserve the breeding stock. This will decrease the yield but leads for simplicity in administration. The maximum yield, without the possibility of biological overfishing, requires the reintroduction of 5-in. mesh nets and encouragement to the fishermen to fish more nets. At the maximum sustained catch level the catch per unit effort will be sub-economic by present standards, so that, to

encourage the required amount of fishing, it would be necessary to increase the price of fish ashore.

The monetary values of these various yields are of interest. At present the annual catch of *T. esculenta* can be valued at £27,000. If biological overfishing is to be avoided the effort with 4½-in. mesh nets must be reduced and the yield will also decline to a value of £25,000. If a proportion of 5-in. mesh nets, with increased effort, were introduced to avoid overfishing, but with no change in prices, the catch value would increase to £30,000 (after a temporary decline whilst stocks rebuilt). If the value of the fish was increased, to compensate for the lower catch per net, the value would be of the order of £40,000 per year.

Such changes in fishing would necessarily affect the catch of other species. The effects of the 1956/57 change from 5-in. to 4½-in. nets showed that all the non-cichlid species, i.e. *Bagrus, Clarias, Protopterus* and *Barbus,* give better yields with 5-in. nets. However, *T. variablis* would be virtually lost to the fishery because the species seldom grows to a size large enough to be captured in 5-in. nets. At Masese in 1958/59 the catch of *T. variabilis* from the North Buvuma Island stock valued £8,000. This catch will not increase substantially and should be an acceptable loss if the alternative with continued 4½-in. net fishing is biological overfishing of *T. esculenta* and a catastrophic decline in catches.

Catches of *T. zillii* will also be lost. This species valued at £752 in recent months and there is not yet a distinctive upward trend in the catches in this area to indicate that the population could become so dense as to offset the loss of *T. esculenta.* In any event 4-in. nets appear to be the most suitable for cropping the species and the use of this gear should be out of the question.

The Application of These Findings to Other Areas of Lake Victoria

The above model is extremely elementary in that the rates of recruitment, growth and natural mortality have been regarded as constant when in fact they are known to be density dependent variables. There are no data for complex extensions of the theory and in any event it is doubtful whether these would contribute more to the conclusions. For example, further depletion of the stock is unlikely to increase the growth rate significantly; conversely, increasing stock density would decrease the growth rate which is likely to be detrimental to the fishery. The above outline will probably prove to be very close to the most rational method of exploitation of *T. esculenta* stocks all over Lake Victoria unless the vital parameters of the population can be demonstrated as being significantly different.

However, it is well known that some areas of Lake Victoria are more productive than others. For example, early records of 25 *T. esculenta* per net suggest that the Kavirondo Gulf is far more productive than the North Buvuma Island area which initially yielded 7-8 fish per net. This indicates that the more productive areas will yield a greater catch for the same fishing effort. It does *not* indicate that they can withstand a greater fishing intensity. A greater fishing intensity would increase the catch temporarily, but at the same time it would deplete the population more rapidly and eventually lead to more serious effects. This is particularly important because it means that despite varied productivity, the method of fishing given for the North Buvuma stock is also a good provisional estimate for other areas.

If a more productive stock gives a greater yield for a given fishing effort, it follows that the catch per net will be greater and that biological overfishing will occur at a higher catch per net despite the apparent stock density.

On the other hand the economics of fishing are similar in many areas of Lake Victoria and the yield can be reduced to approximately one fish per net before it becomes uneconomic. Thus, in an area such as the Kavirondo Gulf biological overfishing may occur at a catch per net far higher than the economic overfishing level. Commercial catch records from the Kavirondo Gulf show that the catch per net in that area is *less* than that of the North Buvuma stock so that there is an inescapable conclusion that the Kavirondo Gulf is chronically biologically overfished.

This is not unexpected. The model has shown that intensive gill net fishing may deplete the stocks to a marginal level in the North Buvuma area and in the Kavirondo Gulf there is very intensive seine net fishery in addition to gill netting. Furthermore this seine netting destroys *T. esculenta* breeding sites and catches potential recruits to the gill net fishery. It has been said that comparatively few juvenile *T. esculenta* are taken in these seines at present, but in 1950 E.A.F.F.R.O. recorded one-sixth of the same net hauls of *T. esculenta*

to be juveniles. The present apparent dearth of juveniles does not show that the seine nets have never caught this phase of the life history but that the Kavirondo Gulf has been biologically overfished for some time, causing a complete collapse of recruitment. The loss to Kenya revenue through this inefficient management can be estimated in tens of thousands of pounds if the value of the catches in the North Buvuma area are any guide.

In Tanganyika a slightly different situation may obtain because the price of fish is lower. Records indicate that fishing becomes uneconomic at a catch per net which is slightly higher than in Kenya and Uganda waters. The situation is, therefore, not as serious as elsewhere.

The present findings are also valuable in the light of a suggestion that fish ponds should be established to restock the lake. This idea is manifestly absurd when one considers that, in the Masese area alone, a catch of 1.4 fish per net requires recruitment at a rate of 860,000 adults a year. To double this yield would require a stocking of 70,000 23 cm. adults per month alone. This is not a high stocking rate of *fry* but it is impossible for adults because 23-cm. fish cannot be grown in fish ponds in such numbers: all available evidence indicates that growth has almost ceased at 15-20 cm. The number of fry required would be 350,000,000 per month.

The precarious state of recruitment of *T. esculenta* stocks also has a bearing on the recent appearance of Nile Perch in Lake Victoria. It is supposed, and hoped, that these predators will utilize the vast stocks of unexploited *Haplochromis* in Lake Victoria. But at the same time it is suspected that the size of prey required by a Nile Perch will be related to the size of the Perch. Very few *Haplochromis* achieve a size exceeding 20 cm. and and so it was very disquieting to record recently a 12 lb. Nile Perch with a 25 cm. *Tilapia* in its stomach. This was still a very small Nile Perch (the species may frequently exceed 100 lb.) and clearly the finding bodes ill for those *T. esculenta* that remain.

References

Beverton, R. J. H. "Report on the State of the Lake Victoria Fisheries." Mimeo. Fish Lab. Lowestoft, 1959.

Beverton, R. J. H., and Holt, S. J. "On the Dynamics of Exploited Fish Populations." M.A.F.F. Fish. Invest. Ser. II, Vol. XIX, 1957.

Garrod, D. J.:—

(i) "The Growth of *Tilapia esculenta* Graham in Lake Victoria." Hydrolbiologia, Vol. XII(4), 1959.

(ii) "The Fisheries of Lake Victoria, 1954-1959." *E. Afr. agric. for J.*, Vol. XXVI, No. 1, 1960.

(iii) "The Selectivity of Nylon Gill Nets for *Tilapia esculenta* Graham." Journ. Conseil., Vol. XXVI(2), 1961.

(iv) "An Analysis of Natural and Fishing Mortality of *Tilapia esculenta* Graham in the Gill Net Fisheries of Lake Victoria." (In press.)

Table I—The Parameters Influencing Population Size

Length (cm.)	Weight (gm.)	T (yr.)	M (yr.)	F. 4″	F. 4″	F. 5″	Eggs per Spawning (5 sp. per yr.)
23·0—23·9	243	·275	·0100	9·9			410
24·0—24·9	276	·307	·0100	38·6			475
25·0—25·9	312	·325	·0100	82·5	4·4		540
26·0—26·9	352	·372	·0100	98·9	19·1		630
27·0—27·9	394	·396	·0160	65·5	51·6	1·0	710
28·0—28·9	439	·465	·0240	24·0	89·5	11·0	800
29·0—29·9	488	·517	·1220	4·9	98·0	32·0	910
30·0—30·9	540	·625	·2660	0·5	82·6	73·5	1,010
31·0—31·9	596	·761	·5360		46·9	99·0	1,120
32·0—32·9	655	·929	·7900		25·5	91·5	1,240
33·0—33·9	719	1·314	1·0180		10·2	63·5	1,360
34·0—34·9	786	1·996	1·1240		4·1	34·0	1,490
35·0—35·9	857	4·954	1·1380			17·5	1,630

THE PERFORMANCE OF SINGLE AXLE TRACTORS ON PEASANT COFFEE FARMS IN BUGANDA

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Trials conducted prior to 1958, using single axle walking type tractors in Uganda led to the general conclusion that this type of tractor would not be suitable for use by African peasant farmers. The main reasons for this view were that the power units were unreliable, that the physical effort required to operate the tractors was excessively high, and that the range of implements available was limited. Finally, the users lacked the necessary skill to maintain the machines in good working order and to get the best performances out of the machines.

The development in recent years of versatile single axle type tractors, with a large variety of easily attachable implements, and apparently more reliable engines, has stimulated considerable interest in the possibilities of using such tractors again on small coffee farms in Buganda. In addition, it is generally felt that the standard of knowledge of operators has improved a great deal and could be further improved by the existence of a number of well-equipped training centres for operators.

Preliminary consideration to the subject was given in a contribution [1] to the Symposium on Mechanical Cultivation in Uganda in December, 1958, in which it was shown that a strong case existed for further investigations into the subject. It was shown that the lower capital cost/acre/annum of the single axle tractor could, providing certain conditions were fulfilled, result in a lowering of production cost over hand labour on the one hand, and conventional four-wheeled tractors on the other. The main factors to be examined in order to make an economic assessment of the value of this type of tractor appear to be the following:—the time taken to perform the various operations, the fuel used per unit of operation, the life of the tractors and the spares and repairs bill during the life of the tractors, and, finally, the value of the labour saved by mechanizing the operations.

This paper details some data and observations made on single axle tractors in Buganda which form part of a comprehensive programme in which all aspects of small tractors in a variety of farming systems are being examined.

Buganda peasant coffee farms were chosen for the trials as it was considered that this pattern of farming contained the greatest potential for the use of this type of tractor. Farmers in this area are most likely to be able to afford the capital outlay required for machinery because of the relatively high incomes obtained from coffee and cotton. In addition, the operations that appear likely to require machinery are within the range which modern single axle tractors could possibly handle, i.e. weeding of cotton and food crops, the cutting of grass within permanent crops, the carting of manure, livestock feed, mulching material and produce, and, finally, stationary work such as coffee pulping and hulling, and water pumping.

A great deal of variation exists in the standard of farming practised on these holdings, and it was found convenient to classify them broadly on the basis of whether the farmer worked full time on the holding or part time. The former type of holding was chosen for the trials as they were on the whole larger, better managed and contained less haphazardly planted crops. Also, it would seem logical that this type of farmer is in a better position to supervise and utilize machinery.

The common operations in coffee, using hand labour only, usually consist of one hand digging followed by three to four weed slashings per annum. The labour cost quoted for all these operations is Sh. 300 to Sh. 360 per annum on estates and Government experimental farms, whilst on peasant holdings a figure as low as Sh. 50 to Sh. 60 per annum is quoted. The main reason for this great difference in cost of operations appears to be that more thorough digging is practised on estates,

whereas the digging operation on a peasant farm merely consists of a shallow hoeing. On the whole, too, the gross wages paid to estate and Government employees appears to be higher than that paid to workers casually employed on peasant holdings. On "planned" farms an average charge for these operations is considered to be Sh. 100, to which tractor costs will be compared.

A total of five basic machines varying in size from 3.5 h.p. to 7 h.p. were available for these trials and they are described in Table I.

TABLE I

Tractor No.	Horse-power	Cylinder Capacity c.c.	Engine Type	Type of Fuel Used	Approx. Price in Kampala (including rotavator)	Type of Transmission for Rotavation
					Sh.	
A	3·5	78	2-stroke	Petrol	1,650	Wheelless rotavator†.
B	4·0	98	2-stroke	Petrol	2,540	Wheelless rotavator.
C	6·7	300	4-stroke	Petrol	6,700	Wheel driven.‡
D	5·0	160	2-stroke	Petrol	2,590	Wheelless rotavator.
E_1*	7·0	350	2-stroke	Petrol	6,020	Wheel-driven rotavator.
E_2*	6·50	450	2-stroke	Diesel	7,500	Wheel-driven rotavator as E_1.

* In each case the same tractor was used, except that different power units were used—E_1 having a 7.0 h.p. two-stroke petrol engine, and E_2 a 6.5 h.p. two-stroke diesel engine.

† When rotavating, the forward movement of this type of tractor is achieved by the rotor and can be varied by the operator, depending on how much pressure he exerts on the braking tine at the rear.

‡ When rotavating, the forward movement of this type of tractor is approximately constant, and determined by the driving wheels.

POWER UNITS

The simplicity and low initial cost of two-stroke engines [6] makes it attractive for use in a single axle type of tractor. Considerable progress also appears to have been made in recent years at improving the performance of this type of engine. On the other hand, the somewhat less temperamental nature of the small four-stroke engine is often considered to be of sufficient value to warrant consideration. The availability of three different types of four-stroke engines for tractor D, in addition to a two-stroke presented an opportunity of studying the relative performance of two and four-stroke engines for this type of tractor in more detail. Particulars of the engines used are as follows:—

Engine Type and No.	Horse-power	c.c. Capacity	Type of Fuel Used
2-stroke D	5·0	160	Petroil
4-stoke F	4·5	230	Petrol
,, G	3·5	135	Petrol
,, H	4·5	180	Petrol

A series of replicated trials was conducted with these units rotavating on coffee farms which were so chosen as to be as similar as possible, both in regard to weed height and soil conditions, to farms where the farmers would normally perform hand digging. There was no significant difference in rate of working between the engines, the overall mean rate for these conditions being 6.88 hours/acre.

It was found that there was no significant difference between fuel consumed per acre by any of the four stroke engines as compared to the two-stroke engine, although a significant difference existed between the four-stroke engines G and F. A highly significant correlation was found to exist between engine capacity and fuel consumed per acre for the four engines considered, ranging from 2.011 gallons/acre for the 135 c.c. machine G, to 2.893 gallons/acre for the 230 c.c. machine F. It would thus seem that the two-stroke engine has no marked disadvantages in regard to fuel consumption or rate of work in comparison to the four-stroke engines tried. Whilst the advantage of the four-stroke in ease of starting was readily appreciated, the danger of engine seizure of this engine when tipped for-

ward or backward, a frequent occurrence in single axle tractors, was noted as a very distinct disadvantage.

A two-stroke diesel engine in tractor E_2 was compared to the two-stroke petrol engine of tractor E_1, in similar tractors. Petrol tractor E_1 used approximately 10 per cent more fuel per acre than the diesel-engined E_2, but its rate of work was approximately $1\frac{1}{2}$ times as great as that of E_2 when rotavating.

These results should not suggest that diesel engines have no place in this range of tractor size. The particular engine used in E_2 appeared to be extremely reliable and robust, but the transmission and gear ratios of the tractor, whilst suitable for the higher speed two-stroke petrol engine of E_1, did not appear to be suitable for the lower speed diesel, and thus adversely affected the output of the tractor.

Tillage Operations by Single Axle Tractors

Whilst the effect of rotary cultivation on soil structure is still the subject of considerable diversity of opinion [5], rotary cultivation is, nevertheless, the most effective method of transmitting engine power to soil cultivations in the case of single axle tractors [3].

In a trial comparing rotary cultivation with shallow ploughing as an alternative to weeding, and using the same tractor in each case, it was found that a mean of 60 hours was taken to complete an acre when ploughing, as compared to 6.12 hours per acre when rotavating. In addition, ploughing could only be performed under very much more limited conditions of weed height and soil moisture than rotavating. In general, therefore, ploughing as an alternative to weeding cannot be recommended and the trials were confined to an examination of the tractors with rotavators.

The breaking of a ley crop by rotavator is undoubtedly more expensive than by conventional tractors, but it is nevertheless feasible if the operation is repeated several times.

Wheelless and Wheel-driven Rotavators

The relative merits of wheelless and wheel-driven rotavators as observed in the course of the present trials may be summarized as follows:—

(*a*) As is to be expected, wheelless rotavators are more convenient for cultivating in haphazardly planted crops, and it is also possible to cultivate more closely and particularly in between line-planted perennial crops. Some 10 to 15 per cent of land in the case of wheel-driven rotavators remains uncultivated in coffee.

(*b*) The maintenance of an even depth of cultivation is more difficult with wheelless cultivators than with the wheel-driven rotavators, although wheelless rotavators do make variations in intensity of cultivation possible, and this is a distinct advantage when the weed intensity is variable or where patches of *Digitaria scalarum* are present.

(*c*) More skill and practice are required in order to become fully conversant with the technique of operating a wheelless rotavator than a wheel-driven rotavator. In addition, the physical effort required to operate a wheelless rotavator, although somewhat reduced when fitted with stabilizing overland wheels, is considerably higher than that for wheel-driven rotavators. It was found that the maximum time a man could operate the former continuously was three hours, whilst for the latter a continuous operational time of five hours was considered reasonable.

Rotor Speed and Blade Design

The importance of correct design and rotational speed of rotavator blades for cultivations has been emphasized [4].

In the case of wheelless rotavators, the theoretical "cut" can, naturally, be varied by the operator. It was found, however, that a minimum rotor diameter of 12 in. was essential to handle surface vegetation under the conditions of the trials. At the same time, 12-in. diameter rotors, travelling at 150 r.p.m. (471 ft./min. peripheral speed of rotor), was found to be the most satisfactory combination for this type of tractor as it produced an excellent coarse tilth under normal operating conditions. Tractor D fulfilled this requirement admirably, but the same cannot, unfortunately, be said of A and B.

For the wheel-driven rotavators, tractor E_1, with a blade length of 9 in. (18-in. diameter rotor) handled the surface vegetation encountered most satisfactorily. A rotor speed of 142 r.p.m. (peripheral speed of 670 ft./min.) at a theoretical forward speed of 0.71 m.p.h., giving a theoretical cut every 0.26 in., was generally the most convenient combination for the available power, 7.0 h.p., of E_1. Tractor C was considered to over-pulverize the soil. Its rotor diameter is 13 in., travelling at 250 r.p.m. and giving a theoretical cut every 0.131 in.,

i.e. half that of E_1. It was noted that with the high rotor speeds of C, whilst leading to over-pulverization of the soil, a great reduction in fuel consumption was achieved per acre as compared to E_1.

Three different designs of rotavator blades were available for tractor D, namely the L-shaped type, the curved type and the scimitar type, illustrated in Fig. I. The curved and L type used, respectively, 30 per cent and 58 per cent more fuel per acre than the scimitar type. The curved and L type blades produced very much the same type of tilth, whereas the scimitar type was found to be effective in light weeding work, but less so under heavy conditions of operation. It would thus seem that the curved type could be recommended for general use in spite of its higher fuel use as compared to the scimitar type.

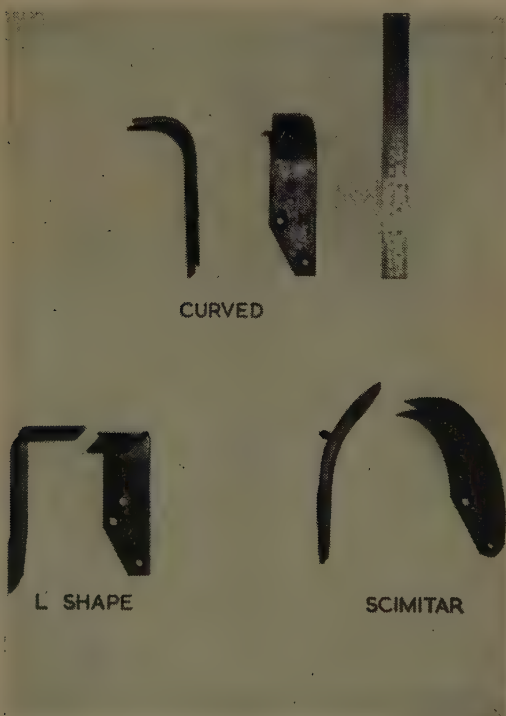

Fig. I.—Details of the three types of rotavator blades compared during trials with tractor D

Six Tractors Compared on Rotavation

The six tractors described in Table I were compared when rotavating coffee. The results obtained with respect to rate of work and fuel consumption are presented in Table II and are based on four replicated runs, each of approximately one hour duration.

The high coefficient of variation for the wheelless rotavators A, B and D in regard to output is inherent and an explanation for this lies in the dependence for its forward motion on the manipulations of the operator. For the wheel-driven rotavators, the low coefficient of variation of tractor C as compared to E_2 and E_1 could be attributed to the former tractor's high rotor speed which would result in it being less affected by changes of soil and vegetative cover, but at the cost of over-pulverizing the soil.

Tractors A and B appear to give the poorest performance. Whilst this would undoubtedly affect the cost per acre, it may not, as will be shown later, be sufficiently large to offset the lower capital cost per acre as compared to the more highly priced machines. The quality of work produced by tractor A, B and C were considered to be decidedly inferior to those of D, E_2 and E_1.

Subsequent trials in light cotton cultivation showed that tractors A and B were able to reduce the time taken per acre and fuel/acre by one half or more of that of heavy cultivation. Tractor D reduced to one-third the hours/acre and fuel consumption. The wheel-driven rotavators C, E_2 and E_1, were not, as could be expected, markedly affected by terrain in respect of rate of work, but fuel consumed per acre was about halved in each case. The overall effect was that for light cultivations one could expect a much closer relationship between output and fuel consumed by the different tractors and the advantages of tractors C, D, E_2 and E_1 over A and B would be minimized.

Other Operations by Single Axle Tractors

As has been pointed out earlier, most modern single axle tractors have a number

Table II—Mean Fuel Used and Hours Taken Per Acre for the Six Tractors when Rotavating

	A	B	C	D	E_2	E_1
Fuel used (gal./acre) ..	4·22	4·67	1·37	2·20	1·69	1·87
Rate of work (hr./acre) ..	7·96	9·46	4·98	6·12	6·13	3·998
Coefficient of variation ..	28·2%	23·1%	6·8%	21·9%	16%	16·1%

of attachments and implements which could be useful to farmers in the area. The main ones are considered to be grass cutting, coffee pulping and hulling, water pumping and farm transport.

Grass Cutting

Three of the tractors tested had reciprocating mowers available for grass cutting. Whilst performance figures in all three cases were considered satisfactory—$\frac{3}{4}$ to $1\frac{1}{2}$ hours per acre, with a fuel consumption varying between $\frac{1}{3}$ and $\frac{2}{3}$ gallons of fuel per acre, there are a number of fundamental weaknesses to this type of cutting mechanism, particularly under peasant farming conditions. The prime weakness originates in the irregular terrain which causes the cutter bar to dig into the soil frequently with resultant bending, and thus increasing the wear of the knife guides. A further problem is that there is no need for cutting grass below a height of 3 in. under normal conditions in coffee, and this is difficult to achieve with the type of machine tried, as it appears more convenient at lower cutting heights. Other problems observed are excessive vibration when aiming at maximum output; wear of the pitman blocks and consequent lost motion of the blade; chipping of the knife sections due to the presence of stones and stumps; and the difficulty of cutting row-planted elephant grass when axle fouling is the limiting factor causing wheel spin. Machines with cutter bars offset to the centre-line of the machine are particularly advantageous when tall grass is to be cut—a frequent state of affairs in peasant agriculture. On the other thand, steering was found to be difficult with this machine, even where differential speeds in the driving wheels were achieved by a ratchet device within the wheels.

It is considered that a rotary grass slasher of superior design and using blade sections of substantial dimensions could be applied with ease to single axle tractors. Whilst this type of cutting mechanism may not be suitable where the grass is to be cut for hay or other livestock feed, it has undoubted advantages because of its relative freedom from the troubles which beset reciprocating mowers in this country, and because of its likely use in the farming system under discussion, where grass slashing/topping would appear to be the most important operation.

Transport

Trailers were available at the time of the tests for tractors B, D, E_1 and E_2. Observations were made over a return distance of 15 miles on a typical Buganda road with a maximum road gradient of 12 per cent. In all cases 5 × 12 wheels were fitted to the tractors and standard wheel and tractor weights added. Table III shows the data obtained in these runs.

TABLE III

Tractor	Miles per Gallon	Mean M.P.H.	Max. Convenient Payload
			lb.
B	14·04	7·15	900
D	20·90	6·40	800
E_2	37·76	6·55	900
E_1	19·37	7·58	1,000

The maximum payload excluded the weight of the driver which was, in each case, 175 lb. These results were on the whole disappointing from the point of view of fuel consumption and possible cost per ton-mile, except in the case of E_2, the diesel-engined tractor. The average speeds were low, but probably the safest for this type of tractor.

The standard charge for load transport in Uganda is quoted at Sh. 0/80 per ton-mile. Fuel and oil alone for a tractor doing 20 miles per gallon, and carrying a load of half a ton, would cost Sh. 0/40 per ton-mile. Only Sh. 0/20 per half ton-mile is, therefore, allowable to cover all other costs of transport with single axle tractors to break even with the standard charge, and this is unlikely to happen. This is not unexpected, but one can nevertheless anticipate benefits from this form of transport where alternative means of cheap transport are not available, i.e. on the farm itself for carrying mulch, farmyard manure or livestock feed and possibly to transport produce to the main roads.

Fig. II.—A coffee pulper driven by tractor D

Coffee Processing

Tractor D was supplied with a coffee pulper attachment, as shown in Fig. II.

This use of the single axle tractor may present, perhaps, its most useful application in Buganda. There seems to be no reason why a water pump and other stationery machinery should not equally well be driven by such an arrangement. In test runs, on robusta coffee, the machine illustrated had a mean throughput of 900 lb. of coffee cherry per hour. Petroil consumption was .33 gallons per hour. The quality of the work was good and no water was necessary in the pumping process.

THE CHOICE OF SINGLE AXLE TRACTORS

Using the data in Table II, the time taken in rotavating with single axle tractors enables one to determine the theoretical maximum acreage which could be cultivated and slashed by each of the tractors considered, using the following assumptions:—

All rotavations to be performed during a twelve-week period each year and wheelless rotavators could be handled for three hours per day only on this work, and wheel-driven rotavators for five hours per day. That is, in a twelve-week period, tractors A, B and D could cultivate 12 × 6 × 3 hours or complete 216 hours, and tractors C, E_2 and E_1 12 × 6 × 5 hours or 360 hours of work per season on rotavation alone. On this basis one could calculate the acreage of coffee which each tractor could theoretically deal with per year by dividing the mean hours/acre, as shown in Table II into 216 and 360 hours, respectively, and this is represented in Table IV. The slashing operations are assumed to occupy the tractors in each case over the balance of the year.

TABLE IV—THEORETICAL ACREAGE OF COFFEE THAT COULD BE WEEDED AND SLASHED PER ANNUM FOR THE SIX TRACTORS TESTED

Tractor	A	B	C	D	E_2	E_1
Approximate acreage of coffee farm	27·00	23·00	72·00	35·0	35·0	90

Assume further than all tractors and implements depreciate over five years, regardless of annual work done, and that the spares bill over the life of a tractor would amount to its initial cost. Also, assuming performance figures as shown in Table II are achieved, then the relationship between estimated cost/acre/annum for the various farm sizes can be calculated, and these are presented in Fig III. An additional labour charge of Sh. 10 per acre has been added to tractor cost in the case of wheel-driven rotavators C, E_2 and E_1 to handle land not cultivable by this type of tractor. Only the more important range of farm size is covered by Fig. III, but it should be noted that the curves for tractors E_2, E_1 and C could be extended to, respectively, 58, 90 and 72 acres at corresponding costs of Sh. 88, Sh. 60 and Sh. 60 per acre per annum.

In the absence of conclusive data on the life of these tractors, the assumptions used in obtaining Fig. III were based on those suggested by Korn [2], except that he adopts for Europe an operational life of 6,000 hours at 400 hours per annum, with depreciation rated at 15 years, as compared with approximately one-third of the life adopted in these calculations. Any improvement in life or operational efficiency over those assumed for East African conditions could thus greatly alter for the better the cost characteristics for these tractors.

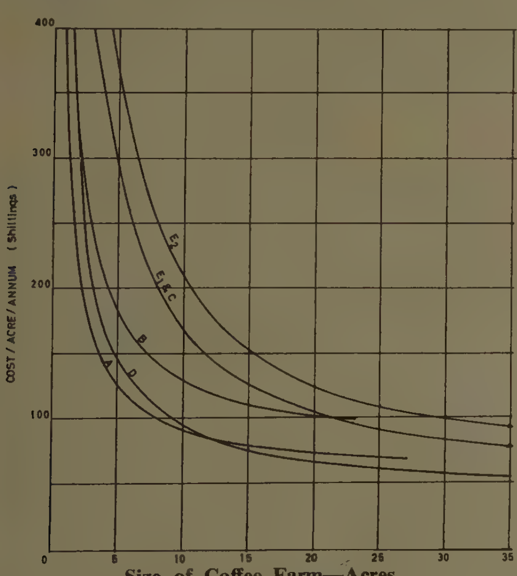

Fig. III—Comparative cost per acre per annum of six tractors on varying sized coffee farms

Fig. III illustrates that, if the cost of hand labour for these operations was assumed to be Sh. 100, all tractors would at some farm size perform the work more cheaply than hand labour. Tractors A and D, however, appear to be the only two machines capable of performing the weeding and grass slashing operations on coffee farms more cheaply than hand labour in the range of farm size predominating in Buganda.

The choice of tractor can, however, be markedly affected too by such considerations as quality of work produced, competence of local agents, and initial capital outlay required. Taking all these factors into consideration, only two of the tractors, namely D and E_1, appear to fulfil most of these requirements. Tractor D would be preferable on coffee farms of between 9 and 35 acres, or where between 150 and 400 hours of productive work could be undertaken per year, and tractor E_1 on coffee farms of between 35 and 90 acres where between 400 and 650 hours of productive work per annum would be possible. Tractor D is, however, likely to be adversely affected by inexperienced operators when compared to tractor E_1. The effect of operational inefficiency on the cost characteristics of D is shown in Fig. IV. The shaded portion shows the range of cost that tractor D could operate depending on the efficiency of the operator. It will be noted that both the maximum farm size that it could handle and the cost/acre are markedly affected by inefficiency of operation and bring the cost characteristics very close to those of E_1 in the most important range of farm size.

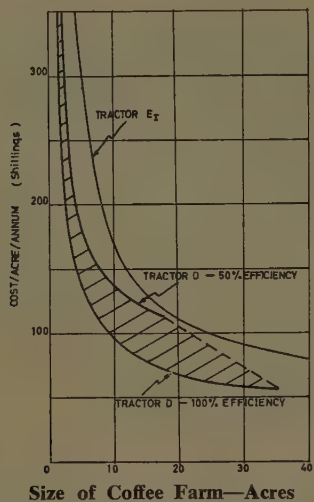

Fig. IV—The effect of inefficient operation of tractor D

Conclusions

Indications are that of the improved modern single axle tractors tried, tractors D and E_1 could satisfactorily perform the operations of weed control in coffee as practised by peasant farmers in Buganda at present, with the proviso that a rotary type grass cutting machine would be a more useful machine than the reciprocating mower for grass slashing operations. It would appear, too, that on the whole the two-stroke engine would be preferred for tractor D over the four-stroke version, and that the curved type rotavator blades could be advocated.

Whilst tractors D and E_1 were considered at this stage to be the most satisfactory in general, their economic employment is subject to certain requirements being fulfilled. In the first instance, if the sole intention is to use the tractors on weed control in coffee, the size of coffee acreage worked per annum should be at least greater than 30 acres before these tractors could be considered to do the work sufficiently cheaper than hand labour to make them a satisfactory proposition. This size of coffee acreage is considerably greater than the average farm size in Buganda, but farmers could overcome this problem by utilizing the tractors productively on operations other than weed control in coffee, e.g. water pumping, coffee processing and transport—operations for which these tractors have proved most suitable, and thus make up for restrictions in farm size; or undertake contract work, or be prepared to use the tractors for considerably longer than five years at a restricted annual rate of work.

The skill of operators, both in operation and servicing and maintenance of tractors, is of very great importance, as it ultimately affects the cost characteristics of these tractors more markedly. An investigation into suitable methods of training operators in this type of mechanization has, therefore, been initiated.

Summary

The results and observations of trials on a number of single axle tractors on peasant coffee farms in Buganda are recorded. Two of the tractors appear to be satisfactory in general, but for their economic employment in the area certain conditions have to be fulfilled, more especially ensuring that they are fully occupied on productive alternative work on the smaller farms.

The importance of efficient operation and maintenance of these tractors is emphasized, and the need for the development of a technique for the training of farmers is suggested.

Acknowledgements

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References

[1] Boshoff, W. H., and Joy, J. L. "Small tractors in small-size African farming." Report of a symposium on mechanical cultivation in Uganda. Department of Agriculture, Uganda, 1960.

[2] Korne, W. *"Einachsschlepper, Kleinbauernschlepper", Land-technik,* Munch, March, 1951, p. 209.

[3] Korn, W. *"Der Einachsschlepper in de Landwirtschaft." Land-technik,* Munch, 1957, *12* (9), 174.

[4] Pereira, H. C., and Jones, P. A. "A tillage study in Kenya coffee: Part II—The effects of tillage practices on the structure of the soil." *Emp. J. Exp. Agric,* 1954, *22* (88), 323.

[5] Scott, P. F. C. "Engineering problems in overseas agriculture: VII—The provision of a tractor for African smallholdings." *J. Agric. Eng. Res.,* Vol. 5 (i), 1960, p. 123.

[6] Towle, A. "Problems encountered in the lubrication of small two-stroke petrol engines." Proc. I Mech. E., Automobile Division, 1958-59, p. 141.

THE ESTABLISHMENT AND PRODUCTION OF A LEY

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The planting of grass leys by the European farming community in the Mount Kenya area was of minor importance before 1955. From 1955 onwards increasing acreages of land have been put down to leys and by 1958 it was estimated that some 5,700 acres were under planted grass [1].

The area concerned lies between 6,500 and 8,000 ft. above sea level on the Equator. It experiences two rainy seasons per annum, the short rains from September to December, and the long rains from April to June. The average rainfall varies from about 27 to 35 in., the rainfall increasing with altitude. The rainfall pattern varies slightly throughout the district but in the Naro Moru area 38 per cent of the rain falls in the short rains and 37 per cent in the long rains. The driest months are February and March prior to the long rains, and July, August and September prior to the short rains.

Like many other parts of Kenya, the soils were known to be deficient in phosphate. In addition, the ploughing up of land for arable cropping resulted in heavy colonization by indigenous Kenya White Clover (*Trifolium semipilosum*).

Two questions were invariably asked by farmers contemplating the planting of grass leys:—

(i) What kind of phosphate should I apply to establish the grass?

(ii) Is it necessary to plant clover when it comes in naturally?

The question of splitting the phosphate application between a seedbed dressing and a top dressing after establishment was also raised on several occasions. Since no experimental evidence to answer these queries was forthcoming from within the district, a trial was initiated in 1957 to seek the answers.

Experimental

The site chosen for the experiment lies at an altitude of 7,000 ft. at Naro Moru, Kenya. The soil was typical of much of the soil at that altitude in the district, being a brownish grey clay loam, occurring on ridges on the westerly slopes of Mount Kenya.

Like most of the fields in the area, the one chosen for the experiment had been under cereal cultivation for five years with two cereal crops per annum being taken on occasions. Each cereal crop had received 100 lb. of triple superphosphates or their equivalent per acre. The chemical analysis of the soil together with pot test results confirmed that the soil was moderately deficient in phosphorous and revealed that the minor element status appeared satisfactory. On the basis of the soil reports no basic dressing was used to correct minor element deficiencies if such existed.

The fertilizer treatments were incorporated in a randomized block design with four replications. The nine treatments were as follows:—

1. Control—no fertilizer dressing.
2. Triple superphosphate at 100 lb./acre with the seed.
3. Uganda rock phosphate at 500 lb./acre with the seed.
4. Basic slag at 250 lb./acre with the seed.
5. Triple superphosphate at 50 lb./acre with the seed and 50 lb./acre as a top dressing.
6. Uganda rock phosphate at 250 lb./acre with the seed and 250 lb./acre as a top dressing.
7. Basic slag at 125 lb./acre with the seed and 125 lb./acre as a top dressing.
8. Triple superphosphate at 50 lb./acre plus Uganda rock phosphate at 250 lb./acre with the seed.
9. Triple superphosphate at 50 lb./acre plus basic slag at 125 lb./acre with the seed.

Each plot was split at random for seeding with inoculated clover and no sown clover. There were in all, therefore, 72 plots in the experiment.

Fertilizer treatments were designed to give the same rate of citric soluble P_2O_5, i.e. 40 lb. P_2O_5/acre.

Rongai Rhodes grass, being the most popular ley grass in the district at the time, was chosen as the ley species and sown at the rate

of 10 lb./acre. Clover plots received in addition 2 lb./acre of Kenya White Clover inoculated with half a unit of inoculant obtained from the Scott Agricultural Laboratories. Kenya White Clover was chosen since this clover was being recommended to farmers on account of its hardiness and its ability to withstand poor management. The indigenous clover in the area was also Kenya White Clover and it was hoped that the more efficient Rhizobium inoculant on the planted clover would in time nodulate the indigenous clover in adjacent plots. The clover was, as a result, inoculated at five times the recommended rate.

Sub-plots occupied an area of 0.0275 acre and were sown with a John Deere combine seed drill. Calibration of the machine for the sowing of the grass seed, various fertilizers and fertilizer mixtures was effected by weighing the fertilizer or seed that issued from the sowing spouts, when the machine was towed by tractor over a set distance on land similar to that on the field.

Observations

Plots were sown on a fine seedbed on 28th-30th October, 1957. Emergence was slow on all plots and in February the trial was mown to remove weeds and volunteer barley. Following the mowing, the Rhodes grass came away on all plots though growth was still slow.

Examination of the sward in March, 1958, revealed that clover was present in all plots but that the plots sown with inoculated clover were discernible by the larger leaf area of the clovers present compared with the clover on the plots not sown with clover.

At the first cut in June, 1958, the inoculated clover plots were distinctly greener and taller than the "volunteer" clover plots and actually contained less clover than the latter (25 per cent estimated cover compared with 35 per cent). The Rhodes grass was also more vigorous with distinctly larger and more numerous seedheads. The volunteer clover plots possessed an abundance of Kenya Wild White Clover in spite of the fact that none was sown. This was not considered unusual as the area abounds in this indigenous species.

No visible differences could be detected between fertilizer treatments in the first or subsequent cuts of the experiment, and only in the first cut were differences between the sown inoculated clover and the "volunteer" clover plots detected. Cuts were taken whenever the herbage was dense enough for a good hay cut.

Following harvest the plots were heavily stocked with cattle for three to four days until all the herbage (including the cut herbage) was eaten down. The heavy stocking in this way would be nearer natural conditions than the complete removal of hay crops. After grazing was completed the experimental area was topped and rested until the next cut. This procedure was adopted after every cut. A total of four cuts were taken over the life of the ley.

Results

The results of the four cuts taken are summarized in Table I.

In the first cut a significant difference at the 0.1 per cent level was established between the inoculated clover and the volunteer clover plots. The former outyielded the latter by an average of 15.2 cwt./acre, an increase of 17.65 per cent. No significant clover fertilizer interactions were established.

No significant differences were established between main treatments in the analysis of variance, but a comparison with the control revealed that treatments 4 and 8 were significantly greater at the 5 per cent level.

The second cut was taken on 3-12-58; no significant differences between the main treatments were established in the analysis of variance, although a comparison with the control revealed that treatment 3 significantly outyielded the control at the 5 per cent level. No significant differences between sub-treatments were established, although the volunteer clover plots slightly outyielded the inoculated clover plots. There were no significant interactions between clover and fertilizer treatments.

In the third cut results followed the same trend as the first cut with treatments 4 and 8 outyielding the control at the 5 per cent level. Comparisons were only valid with the control as no significant treatment differences were established in the analysis of variance. In this cut all treatment means, except that of treatment 3, were higher than the control, but as mentioned above only treatments 4 and 8 significantly so. No significant differences between sub-treatments was established although the inoculated clover plots outyielded slightly the volunteer clover plots.

The short rains at Naro Moru did not commence until mid-November, 1959, and by the

TABLE I—YIELDS IN CWT. PER ACRE OF GREEN MATERIAL FOR ALL CUTS

Treatment	1st cut	2nd cut	3rd cut	4th cut	Combined Total for all Cuts	Significance
1. Control no fertilizer . . .	89·0	60·3	31·7	10·6	191·6	
2. 100 lb./acre Triple superphosphate	91·3	66·9	41·8	12·9	212·9	
3. 500 lb./acre Uganda Rock Phosphate	82·9	75·7	29·3	11·9	199·8	
4. 250 lb./acre Basic Slag . .	109·1	63·1	53·1	15·3	240·6	Treatments.
5. 100 lb./acre supers split with seed and top dressing	78·6	66·9	42·7	10·5	198·7	4 and 9.
6. 500 lb./acre Uganda Rock Phosphate Split	98·2	66·7	38·2	10·6	213·7	All greater than treatment 1.
7. 250 Basic Slag split . .	86·9	68·6	42·9	13·0	211·4	All greater than treatment 1.
8. 50 lb./acre supers + 250 lb./acre U.R.P.	109·3	65·2	52·3	12·6	239·4	
9. 50 lb./acre supers + 125 lb./acre Basic Slag . .	99·0	69·4	35·1	13·9	217·4	
S.E. of Single Plot . .	13·5	9·6	8·6	1·7	16·7	
C. of V.%	14·4	14·4	21·1	13·4	7·8	

end of December dry conditions again prevailed. The rains in November stimulated a flush of clover, but this had dried out by harvest on 14-3-60 when the fourth cut was taken. By this fourth and last cut the sward was rather thin and lacking in bulk, large areas being colonized by Kenya White Clover. No other weeds were apparent though the weed grass *Sporobolus* was in evidence, particularly on the control plots.

Treatments 4 and 9 were shown to be significantly greater than the control at the 5 per cent level. The volunteer clover plots slightly outyielded the inoculated clover plots, but not significantly so. Again only comparisons with the control could be made as treatment differences did not attain statistical significance in the analysis of variance. Over a total of four cuts fertilizer treatments just failed to reach significance at the 5 per cent level. Sub-treatments and the interaction between fertilizer treatments and sub-treatments were shown not to be significant although the inoculated clover plots overall outyielded the "volunteer" clover plots. Overall there was a difference of 10 cwt./acre between the inoculated clover and the volunteer clover sub-treatments in favour of the planted clover. This was almost entirely due to the increase in yield at the first cut. The mean yields for the sub-treatments over the four cuts are shown in Table II.

TABLE II—MEAN YIELDS OF THE SUB-TREATMENTS IN TONS FRESH GREEN MATERIAL/ACRE

Treatment	Cut 1	Cut 2	Cut 3	Cut 4	Total
No Sown Clover *a*	4·31	3·50	2·00	0·71	10·52
Inoculated Sown Clover *b*	5·07	3·19	2·08	0·68	11·02
Difference in favour of *b*	+0·76	−0·31	+0·08	−0·03	+0·50

DISCUSSION

The experiment produced two rather suprising results; firstly, the relatively small response of the ley to phosphatic fertilizers and,

secondly, the failure, other than in the first cut, of the inoculated sown clover to produce significantly higher yields than the inoculated indigenous clover plots. With regard to the fertilizer treatments, the mixtures used at planting time together with basic slag at 250 lb. per acre with the seed were fairly consistent throughout the four cuts in giving increased yields over the control. The remaining treatments, except treatment 3 in the second cut, were never shown to be significantly greater than the control for any cut. Yield increases overall for treatments 4, 8 and 9 were 25.38 per cent, 25.01 per cent and 13.58 per cent, respectively. Other treatments increased the yield over the control by amounts varying from 3.69 per cent with treatment 5 to 11.59 per cent with treatment 6. Split applications were inferior to seedbed applications in the case of basic slag and superphosphate, but superior in the case of Uganda rock phosphate. Such differences were not, however, shown to be significant. It is interesting to note that the treatments shown to be significantly greater than the control were all seedbed applications.

The very small responses from superphosphates are rather contrary to results obtained elsewhere in Kenya. Dougal, 1954 [2], obtained a 42 per cent increase in yield of dry matter by the use of 36 lb. P_2O_5 per acre as superphosphate. This response was, however, obtained in the presence of nitrogen. Boswinkle, 1957 [3], obtained no significant responses to phosphate after the second cut in a ley establishment trial at Kitale. In the establishment cut, the water soluble phosphates were more efficient than the citric soluble phosphates, although the efficiency of these non-water soluble phosphates improved after establishment. It is interesting to note that in this trial the yield of dry matter in the third cut from basic slag was greater than that of all other forms of phosphate tried. This difference was not shown to be significant. At Kitale [4] a fertilizer trial on the establishment of Nandi Setaria revealed that over all cuts superphosphates was the most effective form of phosphate. Basic slag at 50 lb. P_2O_5 per acre appeared to have a greater persistence than the superphosphates soda phosphate and rock phosphate, and was the only fertilizier tried which gave a significantly greater yield than the control in the third cut. After eight cuts, the greatest difference between fertilizer treatments was only 2.54 tons of fresh green material, i.e. an increase of only 15 per cent.

At Molo, Birch, 1959 [5], reports linear responses to phosphate applications on grass and clover up to 189 lb. P_2O_5 per acre. Superphosphates again gave the highest yield responses, though these were not always significantly greater than the basic slag treatments. Rock phosphate treatments were shown to be relatively ineffective. He concluded that optimum rates of application (broadcast) lay between 168 and 252 lb. P_2O_5 per acre. Top dressing with phosphate (basic slag) on a Westerwolth's ryegrass ley produced no significant increase over the control. This bears out the reduced efficiency of split dressings obtained with slag and supers in the present experiment.

The results obtained from the mixtures of superphosphate and slag and superphosphate and rock phosphate were most encouraging. The aim was to apply a quick and a slow-acting fertilizer with the seed to give an initial boost to the crop, followed by a gradual release of phosphate to maintain yields. This has apparently occurred, though the reason for the superiority of the rock phosphpate mixtures over the slag mixture is not understood. However, Neller, 1960 [6], in a paper to the Grassland Congress has stated that sulphur may increase the rate of release of phosphorus from a poorly soluble phosphate such as rock phosphate. No work on mixtures has been reported on for East Africa but, in Rhodesia, Pawson, 1957 [7], states that it was the practice to use a mixture of superphosphate and rock phosphpate under wartime conditions when sulphur was in short supply. The responses to the mixture were greater on soils low in phosphorus. If the efficiency of Uganda rock phosphate can be improved by mixing it with superphosphate, then the utilization of the Uganda supply could be far greater than what it is today. Such mixtures would also be more economic than the use of straight superphosphate or rock phosphate.

Rock phosphate alone showed up in a relatively poor light compared with the other fertilizers used and this confirmed the results in other parts of Kenya. Cooke, 1956 [8], has shown that the Uganda rock phosphate compares very unfavourably with Gafsa or Morocco phosphate in pot tests, the immediate effect on growth being very small indeed.

The response from the planting of inoculated Kenya White Clover has been very disappointing. At the first cut visual observations indicated that the inoculated clover was having a

very beneficial effect on the sward. These observations were confirmed in the yields obtained. That the clover was supplying nitrogen to the grass cannot be doubted since the bulk of grass from the clover plots was greater than that from the no-clover plots. Failure of the clover plots was, in all probability, due to the invasion of the sown clover by rogue strains of Rhizobium which occur on the indigenous clover. Certainly the theory that the Rhizobia supplied in the inoculant would spread to the indigenous clover has not worked out in practice. The possibility that deficiencies of minor elements reduced the efficiency of the inoculant seems rather remote. In the first place, soil analysis revealed no such deficiencies. Secondly, a response was obtained in the first cut. Thirdly, no slag/clover interactions were established. Had certain minor elements limited efficient nodulation, such an interaction would have been expected.

The results of the experiment indicate, therefor, that where Kenya White Clover is indigenous and accompanied by inefficient strains of Rhizobia the planting of inoculated Kenya White Clover cannot be recommended. Even high dosages of inoculant have failed to maintain increased yields beyond the first cut.

That legumes can fix nitrogen under Kenya conditions has been convincingly demonstrated by Bumpus, 1957 [9]. Under conditions at Kitale marked phosphate/inoculant interactions were obtained with many legumes including *T. semipilosum*. In the present trial no phosphate/inoculant interactions were obtained even in the first cut. This may have been due to a higher initial phosphate level in the soil compared to that encountered at Kitale, especially as there may have been a residual phosphate effect following the five years cereal crops prior to planting the ley. However, no residual effects from applications of superphosphate have yet been found in trials carried out to determine "residual phosphate" in other areas of the district. It seems, therefore, that the phosphate status of the soil was not a limiting factor to effective nodulation and nitrogen fixation.

One of the most striking results of the experiment was the rapid fall in productivity with successive cuts.

From Table III it will be seen that this fall off in productivity was neither associated with the variation in the days between cutting nor the rainfall.

TABLE III—THE RELATIONSHIP BETWEEN YIELD, DAYS BETWEEN CUTTINGS, AND RAINFALL

Cut	Yield	As % of Total	Days between Cuts	Yield/ Day	Rainfall	Rainfall/ Day	Yield per inch
	lb.			*lb.*	*in.*		
I	10,507	43·54	218	48·2	23·49	0·108	447
II	7,502	31·06	180	58·3	11·61	0·064	646
III	4,571	18·95	274	16·7	21·92	0·080	208
IV	1,387	6·45	186	7·5	14·55	0·078	95
Total	123,967	100·00	858	—	71·57	—	—
Mean	5,992	25·00	214·5	27·9	17·89	0·083	335

The fall off in yield is shown to be correlated directly with the age of the sward. This decline in productivity associated with the age of the ley is appreciated only too well by farmers and is often accompanied by an increase in the indigenous clover. Such colonization by clover was noticed in the trial in spite of the fact that the cutting management favoured the grass. The authors believe that this marked decline in productivity after the first, and particularly the second, year of the ley is due very largely to nitrogen deficiency. The indigenous clover appears to be far more efficient in obtaining what little nitrogen is present in the soil, and hence the grasses suffer severe competition and nitrogen deficiency. That nitrogen and not phosphate was the limiting factor is further supported by the fact that effects of inoculant in the first cut were more marked than phosphate treatments, this being undoubtedly due to the nitrogen produced by the legume.

If leys in Kenya are to produce economically throughout their life the duration of the ley will have to be reduced—say to two years—or some method found of supplying nitrogen economically to the sward. Experimental evidence has shown that the effect of phosphate applied to the seedbed usually lasts for only three or four cuts and that top-dressing with phosphate, even on soil known to be very deficient, gives little response. Birch [5] has shown that responses to nitrogenous top-dressings, on the other hand, are very high. Yields of perennial ryegrass being doubled by the application of 61.5 lb. nitrogen and trebled with 123 lb. N. per acre. At Ol Joro Orok (unpublished data) yields of green material have been trebled by the application of 70.5 lb. N. to an H.I. ryegrass ley.

The obvious method of supplying the nitrogen, so necessary to the continued productivity of the ley, is through planted legumes. Work at Kitale [10] has shown that the return of nitrogen in the grass from a Setaria/*T. semipilosum* ley is similar to that from a Setaria ley fertilized with 58.8 lb. N./acre. This result is low compared with responses in temperate climates, but as Birch [11] has pointed out, soil temperatures and, in particular, short days, seriously limit the potential of legumes to fix nitrogen.

In the absence of conditions suitable for efficient functioning of pasture legumes, reducing the duration of the ley, improving soil conditions to enable the legumes to function efficiently, or the use of fertilizer nitrogen will have to be resorted to in an endeavour to prevent loss of productivity.

Summary and Conclusions

An experiment to determine the effects of various phosphatic fertilizers used straight or as mixtures, as seedbed applications or split applications, on the establishment and production of a Rhodes grass ley in the presence and absence of inoculated clover is described.

Over four cuts basic slag, a mixture of Uganda rock phosphate and superphosphate, and a mixture of basic slag and superphosphate, all at 40 lb. P_2O_5 per acre, significantly increased yields of fresh green material above that of the control. Other treatments were not significantly greater than the control.

The effect of inoculated *T. semipilosum* did not persist after the first cut when a highly significant increase in yield of 17.6 per cent was obtained. The failure of the clover after the first cut was thought to be due to supression of the Rhizobium inoculant by wild strains of Rhizobia from the indigenous clover.

A marked fall in productivity of the ley occurred over the four cuts. Reasons for this decline in productivity are discussed and suggestions made for preventing such fall off in productivity so common in leys at the higher altitudes in Kenya.

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References

[1] Kenya European and Asian Agricultural Census, 1958—an Economic Analysis. p. 44. East African Statistical Department (Kenya Unit).

[2] Dougal, H. W., 1954. Fertilizer Experiments on Grassland in the Kenya Highlands. *E. Afr. agric. J. 19*: 171.

[3] Boswinkle, E., 1957. Dept. of Agriculture, *Ann. Rept.*, 1957. pp. 15-17. Government Printer, Nairobi.

[4] Dept. of Agriculture, *Ann. Rept.*, 1956. pp. 19-20. Government Printer, Nairobi.

[5] Birch, W. R., 1959. High Altitude Ley Agronomy in Kenya. II—The Effect of Phosphates and Nitrogen. *E. Afr. agric. J. 25*: 113.

[6] Neller, J. R., 1960. Proc. 8th Internat. Grassland Congress. pp. 7-10.

[7] Pawson, E., 1957. The Composition and Fertility of Maize Soils in N. Rhodesia. Empire J. Exp. Agric. 1957, Vol. XXV, No. 98, p. 92.

[8] Cooke, G. W., 1956. The Value of Rock Phosphate for Direct Application. *Emp. J. Exp. Agric. 24*: 295.

[9] Bumpus, E. D., 1957. Legume Nodulation in Kenya. 1—Exploratory Field Eperiments. *E Afr. agric J. 23*: 91.

[10] Grassland Research Team, Kenya Dept. of Agriculture, *Ann. Rept.*, 1959, p. 8.

[11] Birch, W. R. 1959. High Altitude Ley Agronomy in Kenya. Part I—Observations on the Climate and Soil. *E. Afr. agric. J. 25*: 35.

INSECTICIDE STUDIES ON THE ARMYWORM, LAPHYGMA (SPODOPTERA) EXEMPTA Walk. IN KENYA

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This species is one of the most important pests of grasses and cereals in Africa, often causing severe damage to pasture and crops. It has been recorded from Tanganyika (Harris, 1937, 1944), Nyasaland, Rhodesia (Jack, 1930, Whellan, 1954), and South Africa (Hattingh, 1941, Faure, 1943).

A similar species, *L. exigua* Hübn. is important in many of the same territories, while *L. frugiperda* S. and A. has similar habits in America. Zimmerman (1958) supports the use of *Spodoptera* as generic name.

Previous Results

An account of the life-cycle and bionomics is given by Whellan (1954) and Hattingh (1941) They indicated that control was only practicable when an infestation of gregarious phase larvae had been seen in large numbers. Mechanical means of control were often recommended. Harris (1944) advised the use of fluosilicate and sodium arsenite. Petty (1946) used 5 per cent D.D.T. dust and found B.H.C. to be inferior. In East Africa, Tapley (1951) obtained little control with D.D.T., toxaphene, B.H.C., parathion and aldrin as sprays. Later trials with D.D.T. emulsion at approximately 9 oz. D.D.T. in 20 gallons of water per acre gave fair control.

Swaine (1950) used 2.5 per cent D.D.T. dust successfully against *L. exempta*, and later (1953) found combined 10 per cent D.D.T. plus 3 per cent gamma B.H.C. cotton dust to be effective. Del Valle (1950) used D.D.T. on outbreak areas in Moçambique.

Whellan (1954) found that D.D.T. at 1.5 to 2 lb./acre, aldrin at 0.5 lb./acre, chlordane at 1 lb./acre and parathion at 3.5 oz./acre gave complete or almost complete kills, but presented no figures. Parathion has given 100 per cent control in Ghana (1954). Endrin 0.024 per cent has been used successfully in Kenya (Graham, 1956). In 1956 Whellan obtained complete kill with half a pint of 19.5 per cent endrin in 50 gallons of water per acre.

Endrin has been reported to be very effective against *L. frugiperda* by Hofmaster and Greenwood (1949), an emulsion of 0.25 lb./acre giving almost perfect control. Parathion and isodrin emulsions were also effective. Furr and Calhoun (1952) found endrin at 0.2 lb./acre to be most toxic after 24 hours. Brett (1953) also found endrin to be effective, even at a rate of 2 oz./acre. At 0.25 lb./acre it was more effective than isodrin.

Trial A

Method

The population was a heavy infestation of late instar larvae on short grass near the Scott Laboratories, Nairobi, at an altitude of 5,800 ft. It was part of a general outbreak over East Africa towards the end of 1953.

Larvae were fairly uniformly distributed at a mean density of 580,000 per acre, or 119.3 larvae per 1 sq. yd. quadrat. Each treatment was applied to a square 10 × 10 yd. plot separated by 1 yd. strips. Spraying was by means of a knapsack hand pressure sprayer at 48.4 gallons/acre, and dusting was with a rotary hand duster at a delivery rate depending on the nature of the dust.

The treatments in the first trial were as follows. The insecticide content stated is as given by the manufacturer. The sprays are emulsions.

1. Untreated control.
2. Isodrin 0.065 % spray = 5 oz. isodrin/acre.
3. Endrin 0.065 % spray = 5 oz. endrin/acre.
4. D.D.T. 0.1 % spray = 7.5 oz. D.D.T./acre.
5. Parathion 0.75 % dust = 2.5 oz. parathion/acre (21.3 lb. dust/acre).
6. B.H.C. (mixed isomers) 5 % dust = 2.8 oz. gamma B.H.C./acre (26.6 lb. dust/acre).
7. gamma-B.H.C. 2.9 % dust = 11.4 oz. gamma-B.H.C./acre (3.2 lb. dust/acre).
8. D.D.T. 5 % dust = 8.5 oz. D.D.T./acre (10.65 lb. dust/acre).
9. Derris 0.008 % spray (stated to contain 1.25 % rotenone) = 0.54 oz. derris/acre (based on 0.167 % of "Derrisol" emulsion).

Results

The number of larvae were counted in four random 1 sq. yd. quadrats in each treated area. The results are shown in Table I.

TABLE I—COUNTS OF LIVE LARVAE PER SQUARE YARD QUADRAT 18 HOURS AFTER TREATMENT

Treatment No.	Replicate 1	2	3	4	Mean
1	119	98	93	105	104·0
2	18	11	6	3	9·5
3	1	0	0	1	0·5
4	0	6	1	5	3·0
5	6	5	4	4	4·7
6	36	47	71	39	48·0
7	72	59	25	28	46·0
8	33	25	38	43	35·0
9	32	65	67	94	64·0

Treatment number 3, endrin, is outstanding, while D.D.T., parathion and isodrin are highly effective.

In Table II the data are expressed as mean per cent reductions over the initial counts, corrected for a decrease of 13 per cent in the controls and for non-normality of distribution by means of an angular transformation.

Barletts' test on the natural logarithms of the transformed variances indicates that a common standard error would be inappropriate. When individual means are compared by a t test, however, no significant difference is found between No. 3 and No. 4. For No. 3 and No. 5 $t = 8.5$ for 6 degrees of freedom, significant at 1 per cent level; for No. 2 and No. 8, $t = 4.84$ for 6 degrees of freedom, significant at between the 5 per cent and 1 per cent levels.

Endrin spray is thus not conclusively more effective than D.D.T. spray, but significantly more effective than the rest. The more effective group down to No. 2 is significantly separated from the less effective group below and including No. 8.

Similar counts were also made after three days and eight days. Considerable migration into and out of the experiment occurred, making accurate correction impossible.

Despite the influx into the experiment three days later, isodrin, endrin and D.D.T. spray still appeared to have an effect, while parathion and the rest did not. After eight days, when the numbers of larvae had fallen considerably, there were still practically no live larvae on the plots sprayed with D.D.T. and endrin.

The plot sprayed with D.D.T. remained green while the rest of the area was yellow and parched.

TABLE II—TRANSFORMED AND CORRECTED MEAN PERCENT REDUCTION AFTER 18 HOURS

Treatment No. ..	3	4	5	2	8	7	6	9	1
Percent reduction ..	85·8	81·1	77·5	73·2	54·7	48·5	46·8	37·0	0

TABLE III—COUNTS OF LIVE LARVAE PER QUADRAT

Treatment No.	3 Days after Treatment: Replicate 1	2	3	4	Mean	8 Days after Treatment: 1	2	3	4	Mean
1	158	156	115	128	139·25	27	32	31	22	28·0
2	129	97	133	140	124·75	15	3	3	5	6·50
3	16	41	52	43	38·0	1	0	0	0	0·25
4	123	140	97	93	113·25	0	0	0	0	0
5	Very high, not counted				—	—	—	—	—	—

TRIAL B

A second trial to compare concentrations and volumes of endrin and D.D.T. spray was laid down several yards away under similar conditions, on similar plots, five days later. The treatments were as follows:—

1. Untreated control.
2. Endrin 0.065 % spray = 5 oz. endrin in 50 gal./acre.
3. Endrin 0.13 % spray = 5 oz. endrin in 25 gal./acre.
4. Endrin 0.0325 % spray = 2.5 oz. endrin in 50 gal./acre.
5. Endrin 0.065 % spray = 2.5 oz. endrin in 25 gal./acre.
6. Endrin 0.01625 % spray = 1.25 oz. endrin in 50 gal./acre.
7. Endrin 0.0325 % spray = 1.25 oz. endrin in 25 gal./acre.
8. D.D.T. 50W 0.1 % spray = 8 oz. D.D.T. in 50 gal./acre.

The endrin sprays were emulsions, the D.D.T. a suspension prepared from 50 per cent w/v concentrate.

In this area there were substantial initial differences between the treated areas. Counts of live larvae per square yard random quadrat, each count the mean of four replicates, are therefore expressed as percentages of the similarly obtained individual mean initial counts, for each treatment. These figures are then corrected for reduction in the controls by Abbott's formula.

TABLE IV—MEAN COUNTS OF LIVE LARVAE/SQ. YARD, PERCENTAGES AND CORRECTED PERCENTAGES AFTER 1 AND 3 DAYS

Treatment No.	Initial Mean Count	After 1 Day			After 3 Days		
		Mean Count	Percent Reduction	Corrected Reduction	Mean Count	Percent Reduction	Corrected Reduction
1	97	82	15	0	76·5	21	0
2	87	8	91	89	0	100	100
3	62	12	81	78	0·5	99	99
4	72	14	81	78	0	100	100
5	53	11	79	75	0·5	99	99
6	61	6	90	88	0·5	99	99
7	55	15	73	68	1·0	98	97
8	90	14	84	81	0·75	99	99

Under these conditions, the effect after 24 hours is only of interest in showing the rate of action. The effect after three days is sufficiently obvious for statistical analysis to be unnecessary. All rates of endrin were highly effective, even the lowest rate of 1.25 oz. endrin in 25 gallons of spray per acre.

A greater volume of water gave slightly greater reduction in numbers of live larvae in each case. There was little difference between 8 oz. D.D.T. per acre as a wettable powder and about 2 oz. endrin as an emulsion.

DISCUSSION

The short grass on which the trial took place was ideal for the application of insecticide and for the effect of insecticide on the larvae. On other crops, higher rates might be necessary on account of the added difficulty of application and contact with the insects.

Many of the insecticides are toxic to mammals, and for some of them a minimum period must pass between applying the insecticide and feeding animals on the crop. In addition to this objection, the expense of applying insecticides to less valuable crops such as rough pasture is too great, and only mechanical methods of control, such as beating, might be possible.

SUMMARY

The results of two trials on armyworm larvae in short grass in Kenya in 1953 are given, based on counts of live larvae before and after treatment. Eighteen hours after application, endrin emulsion at 5 oz. endrin/acre in about 50 gal. of emulsion/acre gave 85.8 per cent reduction; D.D.T. emulsion at 7.5 oz. D.D.T./acre gave 81.1 per cent; parathion 0.75 per cent dust at 2.5 oz. parathion/acre gave 77.5 per cent; and isodrin emulsion

at 5 oz. isodrin/acre gave 73.2 per cent. Other materials were less effective. Eight days after application, D.D.T. and endrin were both giving almost complete control.

In a second trial almost complete control resulted at three days after application of concentrations of endrin emulsion sprays down to 1.25 oz. endrin in 25 gal. of water per acre. A volume of 50 gal./acre was slightly more effective than 25 gal. for each rate of endrin. There was little difference between 8 oz. D.D.T./acre as wettable powder and 2 oz. endrin/acre as an aqueous emulsion.

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References

Brett, C. H. (1953). Fall armyworm control on late planted sweet corn. *J. econ. Ent. 46*. 714.

Faure, J. C. (1943). Phase variation in the armyworm. *Sci. Bull. Dept. Agric. S. Afr.* No. 234. pp. 17.

Furr, R. E., and Calhoun, S. L. (1952). Toxicity of organic insecticides to the fall armyworm. *J. econ. Ent. 45*, 5. 892.

Ghana (1954). In *Rep. Sixth Commonw. ent. Conf. London*, p. 239.

Graham, J. F. (1956). *Ann. Rep. Dep. Agric., Kenya*, II, p. 3.

Graham, J. F. (1959). Notes on Kenya agriculture, 7. Insect pests and control measures. *E. Afr. agric. J. 25*. 1. 2.

Harris, W. V. (1937). Annotated list of insects injurious to native food crops in Tanganyika. *Bull. ent. Res. 28*, 483-488.

Harris, W. V. (1944). The armyworm. *E. Afr. agric J. 10*. 1. 2.

Hattingh, C. C. (1941). The biology and ecology of the armyworm, *L. exempta* and its control in South Africa. *Bull. Dep. Agric. S. Afr.* No. 217, pp. 50.

Jack, R. W. (1930). The armyworm. *Rhod. agric. J. 27*. 912 and 1052.

Hofmaster, R. N., and Greenwood, D. E. (1949). Fall armyworm control on forage and truck crops. *J. econ. Ent. 42*. 502.

Hudson, J. R. (1943). Notes on an armyworm outbreak in Nairobi, March, 1940. *J. E. Afr. Nat. Hist. Soc. 12*. 125.

Petty, B. K. (1946). Miscellaneous D.D.T. studies. *Bull. Dept. Agric. S. Afr.* No. 276. pp. 16.

Swaine, G. (1950). *Ann. Rep. Dep. Agric. Tanganyika*, 1950. p. 176.

Swaine, G. (1953). *Ann. Rep. Dep. Agric. Tanganyika*, 1953. p. 57.

Tapley, R. G. (1951). *Rep. Dep. Agric. Tanganyika* (Tech. and Spec. Officers) 1951. pp. 51.

del Valle, R. G. (1950). *Lagarta invasora (Laphygma exempta). Gaz. Agric. Moçam. 2*, 9, 37.

Whellan, J. A. (1954). The African armyworm and its control. *Rhod. agric. J. 51*, 6, 415.

Whellan, J. A. (1956). A new insecticide which can be used in armyworm control. *Rhod. agric. J. 53*, 1, 102.

Zimmerman, E. C. (1958). Insects of Hawaii, Macrolepidoptera. 7, 339.

THE HISTORY OF THE FISHING INDUSTRY OF LAKE VICTORIA, EAST AFRICA, IN RELATION TO THE EXPANSION OF MARKETING FACILITIES

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Recent research has shown that, on Lake Victoria, the current commercial fishing practice of using 4½-in. (stretched) mesh nylon gill nets, to exploit the *Tilapia* populations, has led to economic and possibly biological overfishing of the inshore stocks. A greater yield could be obtained by using 5-in. nets, which would at the same time preserve the biomass of the standing crop and reduce the risk of biological overfishing.

An administration wishing to restore the yield is faced with the unenviable task of trying to re-enforce legislation to restrict the permissible mesh sizes, a step which would inevitably result in a further temporary decline in catches whilst stocks are rebuilt.

It is interesting to show how this parlous state of the fishery can be attributed to the structure of the industry and its marketing facilities in the absence of a positive management policy. Lake Victoria is the most heavily exploited of the great lakes of Central Africa and a consideration of the development of its fishing industry may be of guidance to the development of similar resources on other lakes.

Graham [1] records that Captain Whitehouse, R.N., was the first man to use a net on Lake Victoria during his initial hydrographic survey of the lake in 1898-1909. There are no detailed records of the early history of the lake, but from this it can be assumed that, at that time, the level of fishing was determined by the subsistence requirements of the tribes living near the lake shore. Communication systems were rudimentary and the depth of the available markets inland was governed primarily by the rapid deterioration of fish in a tropical climate. Fish were plentiful, so that an adequate supply could be obtained daily with very little effort and consequently there was very little incentive to increased fishing effort.

In 1908 gill nets of European origin were imported into the territory and rapidly superceded the relatively inefficient indigenous fishing methods. At the same time the Uganda Railway reached Lake Victoria at Kisumu, on the Kavirondo Gulf, Kenya. This gulf was probably the richest fishing ground on Lake Victoria and the ensuing export of dried fish inland by rail appears to have given a boost to fishing activity. Graham remarks on the inadequacy of catch statistics, but notes that during the period 1917-1921 an annual revenue of Sh. 15,000-20,000 accrued from fishing licences sold in the Kavirondo Gulf area. A similar expansion also occurred elsewhere, mainly at the hands of Asian traders buying from African fishermen; for example, by 1922 more than 200 tons of dried fish was being exported per year from Mwanza, Tanganyika.

As in all fisheries the increased fishing effort caused a decline in the catch per net, which, in the Kavirondo Gulf, amounted to a drop of some 75 per cent from the estimated initial catch of 25 fish per net to 7 fish per net in 1920. The alarm generated by the accompanying decline in profits led to a survey of the fishery resources of Lake Victoria. This was carried out by Graham in 1927/28, who recommended that the use of gill nets of 3-in. to 5-in. mesh should be prohibited in order to protect the breeding stocks of the most valuable species, *Tilapia esculenta*. When the necessary legislation came into force it effectively restricted fishermen to the use of 5-in. nets because the fish caught in 3-in. nets were too small to command a market value.

Between 1925 and 1930 the records of fishing licences sold in the Kavirondo Gulf indicate a hiatus in the development of the industry, but between 1930 and 1940 the industry began to expand once more as markets and communications improved. During this period the number of *Tilapia* railed from Kisumu increased by 300 per cent to some five million per year. Fishing licences showed a similar increase and there was a decline in the catch per net from Graham's observed figures of seven per net in 1933 to two per net in the Kavirondo Gulf area in 1940 (Beverton [2]).

In the years following World War II the rapid development of townships, industry and plantation farming led to a drift of labour to the urban and plantation areas. In particular, the labour in the latter areas was largely provided by the migration of traditionally fish-eating tribes away from the lake shores, creating new markets. The parallel development of road and rail facilities, together with the advent of bicycles and motorized transport, enabled fishermen to exploit the new markets and spend their profits on an increasing variety of consumer goods. This created a new incentive for fishing and the basis of the industry thus rapidly changed from a subsistence occupation to a profitable industry.

In these years the established operators prospered, but very few of them thought "beyond tomorrow" and none had traded the earlier profits back into their businesses so that, as the value of fishing became apparent a further expansion occurred by a rapid increase in the number of operators rather than by the enlarging of existing concerns. In Kenya waters the number of fishing licences sold increased from 35,000 to over 60,000 during the period 1949-1953 and a comparable increase occurred in Uganda, although the total number of licences issued was not as high as in Kenya.

There was no accompanying technological advance in fishing boats, gear or fish processing, so that these fishermen were restricted to the inshore grounds by their craft and the preference to market fish in a fresh condition. In consequence the catch per net began to decline once more from the level of two per net, which was a fair average for the inshore grounds of Lake Victoria just after the war. The total catch had increased but, with the structure of the industry, each man was interested in his own profit and the total yield had no direct bearing on the development of the resource.

By virtue of the increased total yield the value of fish remained stable and profits sank to a marginally low level as the catch per unit effort declined. This led enterprising fishermen to experiment with illegal nets of 4-in. to 5-in. mesh which caught fish in a relatively lightly exploited, and therefore more abundant, length range. The catch per unit effort from these nets exceeded the return from 5-in. nets. This advantage was enhanced by a unique feature of marketing practice which has been noted by Beverton [2]. Africans habitually trade by number or volume so that, within limits, fish caught in the smaller meshes commanded the same price as 5-in. net fish despite the fact that they might weigh a quarter of a pound (20 per cent) less. The profit in the smaller meshes was clearly very much greater and led to a rapid influx of illegal meshes, so that legislation became unenforceable with the man-power available for control purposes. It was repealed in 1957 in Uganda and Tanganyika waters, and in 1961 in Kenya.

The use of the smaller meshes led to a very large increase in total catch in some areas, e.g. at Masese, Uganda, the average yield of 165 tons per annum increased to almost 600 tons per annum. Gains of this magnitude attracted a further increase in the numbers of fishermen and the familiar trend of declining catch per net reappeared. With regard to one particular species of *Tilapia,* which is especially important at Masese, the 1953-1956 average of 1.44 per net increased to four or five per net for a few months in 1956/57 and then began to decline as the numbers of fishermen increased. During that period the fishing effort increased by 100 per cent. Although the catch reached four to five fish per net for a short period at Masese the reaction of the stock to the increased fishing was so rapid that by the end of 1957 the catch per net was again declining towards two per net. Clearly the stock could not support the fishing effort if each man was to obtain an economic catch per net and the fishermen began to emigrate when they found that, owing to the biology of the species, gill nets of 4-in. mesh caught even fewer fish.

This has brought the fishery to its present condition where, following a rapid expansion of $4\frac{1}{2}$-in. mesh net fishing in 1956/57, the catch per unit effort has once more declined to a marginally profitable level and the inshore fish stocks have been seriously depleted. As the catch became marginal, fishermen have moved offshore, causing the total yield of the inshore grounds to fall still further, although a sufficient number of fishermen remain operating inshore to keep the fish stock at its present low level. As soon as there is a slight recovery the fishermen return inshore. The fishing effort is self-adjusting at a level returning a marginal profit which is predetermined by the value of the catch per unit effort. On the Masese stock referred to above the present catch per net of the most important species is 1.36, very close to the value 1.44 which obtained before the change in fishing practice.

Hence, although the total catch is higher than before no long-term benefit has accrued to an individual fisherman and, with the tendency to use decreasing mesh sizes this trend may involve a biologically dangerous degree of depletion of the fish stocks.

At the time of repeal of the fishery legislation in 1957, nylon gill nets were introduced which have both a greater efficiency and durability than flax nets, thus increasing profits and decreasing the cost of fishing at the same time. Outboard engines also appeared as fishermen, realizing the necessity of extending their range, began to invest their earlier profits and to make use of credit facilities that were becoming available. Many fishermen now operate from temporary camps on distant islands where they may fish for ten days before returning to market their sun-dried or smoked fish. However, with their limited financial resources no single operator has been able to exploit the obvious opportunity of ferrying fish back to market in a refrigerated vessel. There is considerable room for technical improvement of the fisheries offshore, which are becoming more important so that at present, although it has not been possible to collect adequate statistics from the distant landings, it is probable that the offshore fishery yields about as much as the inshore fishery. For example the present method of sun-drying or smoking are not satisfactory, especially during the rainy seasons and because suitable wood is very limited on the islands.

The situation at present obtaining on the inshore fishing grounds of Lake Victoria will develop in any unrestricted gill net fishery in Central Africa where a market exists. The socio-economic conditions are such that a venture offering any profit will attract new operators. In the fishing industry, even if it does not develop in a series of "explosions" as on Lake Victoria, the gradual expansion of the industry will lead to economic overfishing of the more accessible fishing grounds if there is no guidance in the distribution of effort. This will be followed by a trend to use nets of a steadily decreasing mesh size where, within limits, the value per fish remains fairly steady, regardless of its weight.

In recent years this erosion of the inshore fish stocks of Lake Victoria has had the virtue of forcing fishermen to extend their geographical range, but it has also had serious biological implications. It is a common fallacy in the consideration of fishery resources, to assume that their ability to recover from depletion is so enormous as to make biological overfishing virtually impossible. Whilst this may be true of the highly fecund temperate water species, evidence is accumulating to show that biological overfishing is a very real danger to fisheries based upon mouth-brooding *Tilapias*. These species produce relatively few eggs (full-sized *Tilapia* of this type may produce 1,500 eggs per spawning) so that their potential rate of recovery from excessive exploitation may well be less than that of species producing large numbers of eggs. At the same time these stocks are being exploited by a people who require very little profit so that they can be depleted to a very low level before fishing becomes sub-economic. In the Kavirondo Gulf the original estimated catch per net of 25 was eroded to less than one per net before fishing became uneconomical. Both factors enhance the biological risk.

Recent research upon the population dynamics of the most important *Tilapia* species has shown that when the use of illegal nets of less than 5 in. mesh became widespread in 1956/57 the fish stocks of some areas were underexploited even though the catch was uneconomically low. A level of yield approaching the maximum potential of the stock could have been obtained if a sufficiently high level of fishing effort with 5 in. nets could have been encouraged. At that level the catch per net would have been very low, but because the catch per net responds less rapidly to changing fishing effort at high levels of exploitation, it would have been possible to manipulate fishing effort within the biological requirements of the stock. As it was, the value of individual catches became sub-economic at a level of underfishing where the catch per net still responded rapidly to increased fishing effort. As a result fishermen were forced to use the smaller meshes and control became virtually impossible and, by the time the catch per net with smaller meshes had once more declined to an uneconomical low level, the stock had been seriously biologically depleted.

The difficulty of control of these fisheries can, therefore, ultimately be attributed to the low value of fish, which originally prevented fishermen from varying the price of fish with the catches they obtained, and other structures within the industry which cause the overhead costs of fishing to be relatively higher than if several large concerns controlled all the fishing.

In addition to the yields from other Uganda waters which have offset the declining catches of the inshore grounds of Lake Victoria and so kept fish prices low, two other factors have contributed to the low profits in the area and the resulting difficulty of enforcing controls. These are the conservative dietary habits of the African population and the development of fishmongering.

Crutchfield [3] has discussed fully the marketing structure in Uganda and stresses that in recent years an increasing proportion of income has been spent on fish. This is true, but, as we have seen, this reflects a greater number of fish purchased; it does not indicate an increase in the value per fish, and no benefit has accrued to an individual fisherman, although perhaps more fishermen have been able to make a living.

Many tribes inland are not familiar with fish and though they will buy it at a suitably low price, they do not *insist* upon fish as a constituent of their diet and are quite content to buy elsewhere if the price is wrong. Thus, whilst fish may be sold there is no positive demand for fish. This is exemplified by the recent temporary collapse of the Uganda fishery on Lake Albert as a result of the disappearance of the Congo markets during the recent political crisis; fishermen were not able to sell their fish in Uganda.

One might regard the market structure as erring in emphasis: the population is doing a favour to the fisherman by purchasing his fish at all, instead of the fisherman favouring the population by selling his catch. The fisherman has no control over his prices and, as the number of fishermen increases and individual catches decline, his profit is beyond his control and he is forced to reduce the mesh size, if possible, or fish elsewhere.

In addition to this, fishermen do not always sell their fish directly. No single concern is big enough to control its own distribution facilities and there has been a growth of fishmongering during recent years. This has meant that a large proportion of the revenue spent on fish consumption has been lost to the middleman. This is not entirely new, because in 1917 Graham records the retail price in Kisumu market as 70 cents to Sh. 1 per fish, though they were probably purchased from the fisherman at 30 to 40 cents each. At present both the wholesale and retail prices are slightly higher, but they have not risen in proportion to the cost of living and the cost of fishing. If the fisherman requested a better price the fishmongers would also request a similar increase and the market would disappear, either because cheaper fish can be obtained from an alternative source, or because the population is not sufficiently interested in eating fish.

The fisheries of this Central African lake thus present a curious paradox. The value of fish is sufficiently low to encourage people who are not traditionally fish eaters to buy fish. This, in turn, encourages fishermen to exploit new areas and lakes where in the early days of exploitation a high catch per net is obtained and individuals make adequate profits. Thus far the low price of fish is beneficial to the industry. At a later stage the increased numbers of fishermen attracted by the profits cause the catch per net to decline but the total catch of fish remains high and its availability on shore does not change, so the price remains stable and the profits decline. This eventually compels the use of smaller mesh sizes and the low price of fish becomes detrimental to the fishery because it is impossible to encourage fishing to a level that will return the maximum potential of the resource. Eventually, as on Lake Victoria, this can lead to a state where the low prices have, in the long run, caused a serious biological depletion of the stock.

The above discussion is undoubtedly an over-simplification from an economist's point of view, but to a biologist responsible for the safety of fish stocks, four very important features, which are at present extant in the Central African fishing industries, must be considered by anyone wishing to develop the resources of the East African territories to the maximum yield of protein to the population.

(1) The development of co-operatives or large businesses employing the smaller units should be encouraged from the point of view of the overall economic advantages of this pattern of expansion, and because it will facilitate control should this ever become necessary.

(2) The creation of a positive request for fish from the population, so that the price of fish may vary more readily with the availability of supplies.

(3) The sale of fish by weight rather than numbers so that fishermen can accrue the true value of their catches.

(4) Technological development in parallel to the expansion of the industry. Advance of this type is especially necessary to ensure a more equitable geographical distribution of fishing effort on the larger lakes of Central Africa.

REFERENCES

[1] Graham, M. "The Victoria Nyanza and its Fisheries." Crown Agents, London, 1929.

[2] Beverton, R. J. H. "A Report on the state of the Lake Victoria Fisheries." Mimeo. Fish Lab., Lowestoft, 1959.

[3] Crutchfield, J. "A Report on the Structure of Fish Marketing in Uganda." Mimeo. F.A.O., Rome, 1958.

REVIEW

SYNECOLOGY AND SILVICULTURE IN GHANA by Taylor, C. J. (1960), published by Thomas Nelson and Sons Limited, Edinburgh. Price £5.

This book is the result of the author's service in the Gold Coast (now called Ghana) as an assistant conservator of forests. It is an excellent publication and the need for this assembly of information is shown by the bibliography of 50 items of which comparatively few are written by Gold Coasters about the Gold Coast.

The book is divided into three parts. The first is a general section which includes the history, topography, climatology, soils and life forms (vegetational) of the country. The second part describes the vegetation and divides it into five main forest types:—

(*a*) Tropical high forest (Rain forest).

(*b*) Seral communities in the high forest zone.

(*c*) Savannah woodland.

(*d*) Coastal scrub and grassland.

(*e*) Maritime vegetation.

This accounts for about 76 pages. The third part on silviculture covers some 300 pages and describes about 160 species by families in alphabetical order.

This is followed by nine appendices, a bibliography, index and two excellent maps, one physical and the other of the vegetation zones, which are contained in a rear pocket.

The text is very well illustrated with many line drawings, 120 pages of half-tones and two maps in colour.

Now for comments! The book and its illustrations are exceedingly well produced. It is a great credit to the University College of the Gold Coast and to the Government of Ghana who found the money to enable the publishers to produce such a first-class book.

Its price is high (£5), but how could a production of this size and quality be cheaper? This price puts it beyond the range of the average forest officer, ecologist or botanist—however keen he may be. This means consultation of library copies, which is never so efficient as "having your own".

Reading this book one gets a number of shocks about the country concerning which it is written. Reading the newspapers these days one does not realize what a minute part of Africa Ghana is. It is only 90,000 sq. miles in area with a population of some four million people. Compare this with Kenya's Northern Frontier District of 117,000 sq. miles, i.e. one district of Kenya is considerably bigger than the whole of Ghana.

Further, looking at the map in the rear pocket, it is a shock to see what a very small proportion of Ghana is rain forest, possibly some 5 per cent of the country, or some 4,000 sq. miles. Compare this with the area of dry woodland of Africa south of the Sahara, which is about 5,000,000 sq. miles (or some 1,250 times as large).

To those of us who do not know the country, our idea is that the "White Man's Grave" is just solid tropical rain forest, and yet very rarely is a rainfall over 100 in. met with, and some 75 per cent of the country is described as "Guinea Savannah Woodland" with a very, very much lower rainfall.

In conclusion, we must give Dr. Taylor, his publishers, and his sponsors, full marks for an excellent book that should be on the shelves of all tropical foresters. It is very readable and excellently produced.

A. L. G.

CONFERENCE ON LAND MANAGEMENT PROBLEMS IN AREAS CONTAINING GAME: LAKE MANYARA, TANGANYIKA

20th–22nd February, 1961

PART II

Reported by H. C. Pereira, E.A.A.F.R.O., Muguga, Kenya

(*Part I appeared in the July,* 1961, *issue of this Journal*)

SECTION V—THE DISEASE PROBLEMS OF WILD ANIMALS IN RELATION TO DOMESTIC STOCK

Papers 10-16.—"The role of wild animals in the maintenance and transmission of disease", by East African Veterinary Research Organization.

This group of admirably short and factual papers by members of the East African Veterinary Research Organization was introduced by Mr. Brocklesby, who began by stating firmly that the veterinary profession were not prejudiced against game: they did not believe that elimination of all game would eradicate any of the main cattle diseases from East Africa.

Paper No. 10.—"Rinderpest and game", by G. R. Scott.

Dr. Scott tabulated the six wild species in which natural infections have been proven. These are buffalo, kudu and eland, wildebeest, impala and warthog together with a further list of 11 species which have proved susceptible to infection by direct inoculation.

Paper No. 11.—"Serological evidence for enzootic rinderpest in wildebeest of the Serengeti: Mara: Loita Plains area", by W. Plowright and R. D. Ferris.

Messrs. Plowright and Ferris reported tests on sera from 73 Wildebeest for neutralizing antibody against Rinderpest virus. While only a small proportion of adult animals from the Amboseli-Kajiado-Kapiti area are immune to Rinderpest, all of the adults tested from the Serengeti-Mara-Loita Plains area showed past infection with the virus. Kongoni, Topi, Impala and Gazelle sera, examined in small numbers only, show no evidence of past infection. It is not yet known whether the relatively mild virus strain found in Wildebeest would be of high virulence for cattle.

Paper No. 12.—"Some observations on caprinized rinderpest virus in buffaloes", by R. D. Brown.

Dr. Brown described some direct experiments with cattle and tame buffalo, which showed no transmission of Rinderpest virus to buffalo penned with cattle reacting from K.A.G. vaccine.

Paper No. 13.—"Blue wildebeest and malignant catarrhal fever of cattle", by W. Plowright and R. D. Ferris.

Messrs. Plowright and Ferris reported isolation of malignant catarrh virus from 16 per cent of 50 apparently normal Wildebeest. Uninfected Wildebeest calves, never infected by inoculation, suffered only a mild transient fever, while transmitting the disease in malignant form to bovine calves penned with them.

Paper No. 14.—'The role of wild swine in the epizootiology of African swine fever", by D. E. DeTray.

Dr. DeTray reported that African Swine Fever, which causes an almost 100 per cent mortality in domestic swine, is carried by apparently healthy warthogs in areas where no domestic swine have been introduced. In Kenya strict paddocking of domestic swine, enforced by law, has successfully prevented their infection.

Paper No. 15.—"Wild animals as reservoirs of Theilerial parasites pathogenic for cattle", by D. W. Brocklesby.

Mr. Brocklesby, describing present knowledge of the Theilerial parasites carried by game, associated Dr. Barnett with the studies reported. In cattle *T. parva* causes East Coast Fever while *T. mutans* is ubiquitous and usually harmless. Similar organisms have been found in blood samples from 50 out of 58 Wildebeest. Work in South Africa showed

buffalo to carry a similar infection. Following up this work on strains collected from buffalo in Kenya suggests that after several passages through cattle the buffalo parasite can produce East Coast Fever. Muguga studies had recently isolated a parasite, not transmissible to cattle, which caused death of eland, with symptoms similar to those of East Coast Fever.

Paper No. 16.—"Tick records from game animals", by Miss J. B. Walker.

Miss Jane B. Walker described the wide range of tick species, some of which are specific to hosts such as python, hyrax and elephant. The Brown Ear Tick which is the most important vector of East Coast Fever in cattle, has been found on buffalo and on many species of antelopes. Occurring mainly in areas having over 25 in. of annual rainfall, it is often associated with the tropical bont tick, which is the principal vector of heartwater of ruminants. The bont tick has been collected from carnivores as well as from many antelope species. In the drier areas, Miss Walker described ticks with a wide choice of hosts, but without incrimination as disease vectors. *Amblyomma gemma*, which feeds on both wild and domestic ruminants, has been proved in the laboratory to be a vector of heartwater. The Blue Tick, which transmits both redwater and anaplasmosis to cattle, is rarely found on game animals.

In the discussion, the most effective method of control of parasitic diseases was to clean a fenced and limited area by dipping and careful management, and to keep it clean by preventing the ingress of infected cattle. Helminth diseases depend similarly on dosing and management. Neither can be carried out so effectively in the presence of migrant populations of infected game. While exotic stock are unlikely to succeed without protection, Zebu stock have been known to thrive in game areas.

Paper No. 17.—"A note on the game animal hosts of tsetse flies and the incidence of trypanosomiasis in them", by W. P. Langridge, Kenya Veterinary Department.

Dr. P. E. Glover, who spoke in the absence of Mr. Langridge, described the wide range of the eight known species of tsetse fly in East Africa. Other species of biting flies can also spread trypanosomiasis. A wide range of game species showed from 10 per cent to 50 per cent of trypanosomiasis.

The technique devised by Weitz, to identify from a bloodsmear the animal species on which a tsetse fly has fed, has been most valuable in study of the feeding habits of different tsetse species. Elephant, buffalo, rhino, bushpig, warthot and forest duiker are preferred hosts of four important species of tsetse, although large numbers of plains game were available. The many species of plains game which were to some extent infected with trypanosomiasis suggest that mechanical transmission by biting flies may be of considerable importance.

Paper No. 18.—"Parasites of game in relation to domestic stock", by Dr. S. F. Barnett, Kenya Veterinary Department.

Dr. Barnett presented a formidable list of parasites of game recorded by the Veterinary Department of Kenya.

DISCUSSION

From a wide-ranging discussion on the role of wild game in the maintenance of endemic disease and the spread of epidemic disease there is space here to record only a few salient points.

Although rarely providing the main source of infection wild game do undoubtedly afford some hazard to cattle production. Rinderpest, foot-and-mouth disease, anthrax and rabies could all become very serious hazards if veterinary defences were relaxed.

When living in an environment free of trypanosomiasis there is some evidence that game species usually tolerant to this disease lose much of their immunity.

Rinderpest causes severe losses in wild game and seems to progress from one species to another. The 1960 epidemic among Kenya game in the N.F.D. almost exterminated the Greater Kudu, took about 60 per cent of buffalo and elephant, then laid waste the impala herds, subsequently killed 60 giraffe in six weeks, but did not touch oryx, Grant's or Thomson's gazelles. The epidemic appeared to die out on reaching the European farming area but unfortunately it has since broken through to the Mount Kenya forests, where 84 buffalo and elephant died in three weeks. It may now spread around the mountain and it is feared that the Bongo may also be decimated.

In Kenya, fly barriers are cleared to a width of two miles by bulldozer and chain and are kept bush free by burning every two or three years. Game destruction is regarded as wasteful and ineffective.

In the Ankole/Masaka area of Uganda, after bush clearing and spraying had failed (E.A.T.R.O. tried all methods in a £150,000 scheme), many thousands of cattle and many villages were evacuated while re-invasion of *G. morsitans* in an atypical environment threatened Western Uganda. The game slaughter policy was instituted in the absence of any other reliable method of control, and 30,000 animals have been shot in the last three years in Ankole and Masaka Districts. All species of game are being shot, with the exception of elephant, klipspringer, impala and zebra, to a clearing limit line. The operation has halted the further advance of the fly and is showing every sign of being successful in completely eradicating the tsetse. New methods of spraying with insecticides have now been developed, and these methods will be used in future instead of game destruction, to clear a further thousand square miles up to a line of lakes where the fly advance can be held. An appeal has been made to the World Bank and to I.C.A. for funds to undertake this spraying programme.

In Northern Rhodesia, where two-fifths of the total land area is still infested with *G. morsitans,* two very large fly-barrier clearings are maintained. In addition, there are 200 miles of game fence two metres high. The official policy is to separate game from cattle as completely as possible. Fog-spraying of insecticides at night, under a temperature inversion, had proved successful.

Many speakers expressed doubt as to future means of control of Masai cattle numbers, already seriously in excess, as disease was progressively eliminated.

Section VI—Marketing and Related Problems

Mr. Leslie Brown gave a prepared assessment of the relative economic importance of extensive ranching as compared with intensive livestock industry in Kenya, summarizing the published data for 1957/58/59. From European agricultural enterprises the average gross farm revenue from livestock was £7.9 million for these three years, of which £6 million came from intensive farming, including dairy, pigs, poultry, etc., and £1.9 million from ranching. Approximately £1.1 million came from African pastoral areas, giving a total gross revenue from the extensive livestock industry of £3 million per annum. Against this figure the estimated annual tourist revenue of £5.5 million is impressive.

In all three East African territories the land inhabited by African pastoralists is deteriorating; over many large areas the pasture resources are virtually destroyed as a result of overstocking through lack of off-take. Yet of Kenya's 6½ million people the majority live on a low-protein diet. If every African ate only *1 lb. of meat per week* this would consume 600,000 stock units killing out at 500 lb. per annum, representing a 10 per cent annual cull of the cattle population of 6,000,000. The purchasing power of the African community, as the result of the sale of cash crops, had increased to over £2 million per annum in recent years. This must be the fate of the excess scrub cattle from the pasture areas.

Several speakers quoted evidence that African farmers with cash crop incomes bought large amounts of meat, but were very selective purchasers; fat cattle were always chosen in spite of price, and much of the stock purchased came from European producers.

Lean stunted animals from overstocked areas of the pastoral tribes are very difficult to market. In the Karamoja District the Local Native Council field abattoir lost £10,000 in one year on scrub stock purchased at Sh. 35 per head. They would, in fact, have lost money if the beasts had cost nothing at all since the internal market in East Africa for biltong, meat meal and bone meal has recently dwindled while costs of transport to overseas markets are very heavy. At present there appears to be real doubt, should a "sociological break-through" to the Masai be achieved by which they were persuaded to sell some 15 per cent of their cattle, whether there would be enough market demand for the off-take. Boneless meat for canning appears to be one of the possible outlets, although this needs expensive refrigerated transport.

The biggest difficulty in exporting meat is the inability of East Africa to declare freedom from Rinderpest and from Foot-and-Mouth disease. Complete separation of cattle from migrant game would assist in establishing control. This has already been achieved in the case of African Swine Fever. Canning is the most promising means of export but much of the Masai stock is too poor even for canning. The Kenya Meat Commission factory at Athi River cans a great deal of medium-grade stock, but

the East African pastoral tribes have an exaggerated idea of the value of their cattle. As a result 2,000 head per month are bought from Somali traders. Although trekked down from Somalia their cattle are sold at a realistic price at Mombasa.

On the marketing of game meat, successful reports were made by several members. Since 1958, some 1,600 hippo have been cropped in West Uganda, the carcasses being sold on the spot to contractors at about Sh. 200 each. The meat retails readily at Sh. 1 per lb. in the African villages. Uganda Kob, also cropped systematically, had found ready sale. It is proposed to crop 1,000 elephant a year for three years on a similar basis. In Kenya a cropping scheme for 200 elephant a year is beginning in the Galana region. A major problem is the distance of the game-producing areas from the main consumer areas.

In Southern Rhodesia a pilot cropping and marketing scheme has established the following values on the Bulawayo butchers' meat market:—

Impala	£4 each
Zebra	£8 each
Kudu	£12 each
Wildebeest	£14 each
Buffalo	£24 each
Duiker	£1 each
Warthog	£4 each

These prices could, with advantage, be lowered to increase the volume of trade and to make the different meats better known. At present beef prices and costs, 15,000 to 20,000 acres are necessary for a cattle ranch to break even; yet there are many ranches of 10,000 acres or less. The marketing of game meat could substantially increase productivity and thus assist the latter group of ranches. Government support is urgently required for the better organizing of the meat-handling and marketing facilities and for the enactment of the necessary legal provisions.

The Uganda Government has already applied to F.A.O. for the assistance of a specialist in the economics of meat marketing.

It was agreed that the sale of game meat must not be allowed to impede the off-take of cattle from the pastoral tribes.

Two further papers—

Paper No. 19.—"The use of check sheets to facilitate field recording and subsequent analysis of data", by Lee M. Talbot;

Paper No. 23.—"A proposal that a small reference book be prepared for the use of field workers associated with game husbandry problems", by H. P. Ledger,

were distributed, but time did not permit their discussion.

Section VII—Tour of the Ngorongoro Conservation Area

Paper No. 24.—"East African background to the special problems of Ngorongoro", by A. J. Mence, Game Ranger, Member of the Ngorongoro Conservation Authority.

Mr. Mence described briefly the setting up of the Conservation Area. The objectives of the C.D. and W. scheme by which it is initially financed are:—

(*a*) Reclamation of unpalatable grasslands and the development of good grazing with greatly enhanced carrying capacity.

(*b*) The prevention of trampling and erosion around water supply points.

(*c*) The provision of more widely distributed water points to permit of range management.

(*d*) Additional forest protection and improvement to protect water catchments.

(*e*) Special protection of the wild life in the area to the fullest extent compatible with the reasonable interests to the pastoralists.

The Nuffield Trust has granted £20,000 to provide for research work on (*a*) under the scientific direction of Dr. Russell. The unique status of the area as an internationally known tourist attraction has to be balanced against the agreement with the Masai under which they withdrew from the Moru Kopjes.

Progress has up to the present been slight, because any of the improvements listed postulate the acceptance of some degree of restriction and control by the Masai. The latter have a social structure and traditional grazing habits which have as yet made no visible progress in adaptation to the changing conditions of East Africa. Removal of the biological controls of cattle disease and tribal warfare has led to gross overstocking and the virtual destruction of the grazing potential of much of Masailand. The Conservation Area therefore suffers from infiltration of stock from areas already devastated, and where the only effective biological control on cattle populations is now death from starvation.

The 130 square miles of crater floor support all through the year a population of some

10,000 wildebeest and zebra and some 3,000 to 4,000 gazelle with a few hundred together of eland, waterbuck, reedbuck and kongoni. In addition there are 2,000 resident Masai cattle and 2,000 sheep and goats. There is thus a permanent population of about one stock unit per six acres. In addition, an extra 5,000 Masai stock units enter the Crater during the dry season, to raise the grazing density to a beast per four acres. Well distributed permanent water and a high water table enable the Crater floor to sustain this astonishing carrying capacity.

This water supply, however, is dependent on the hydrological regime of the catchment areas. Uncontrolled burning and severe overgrazing with destructive trampling are reducing the ability of these catchments to supply a steady dry-season flow. As a result the marshes and reedbank areas on the Crater floor, favourite habitat of lion, hippo and wildfowl, are drying up. There is considerable recession of the forest cover on the catchments with burning and overgrazing of the tussock grasses which replace the trees. Dr. Pereira had inspected these catchments and had reported on the hydrological effects, which justify careful catchment protection. He had commented that the destructive and undisciplined manner of the burning and grazing rendered impossible the application of a multiple land use policy as operated in many forest reservations in the U.S.A.

The excessive pressure on the highland grazing, intensified by overstocking from areas outside the Conservation Unit, had resulted in the widespread dominance of the rather unpalatable tussock grass *Eleusine jaegeri*. Dr. Glover and Mr. Newbould are working on this problem on behalf of the Nuffield Trust. By a combination of grazing management and controlled burning it may prove possible to reduce the tussock grass to a palatable state and eventually to eliminate it. Until a system of grazing management can be guaranteed, however, the success of such a scheme would be of questionable value, since the tussock grass is at least a valuable protection against soil erosion.

There is little plains game on the uplands, and negligible competition with stock. In the rains, however, both stock and game concentrate in very large numbers on the Serengeti Plains. With loose volcanic ash soil, high temperatures and sparse rainfall these pastures are very easily damaged. They are now being damaged extensively, the most serious trouble resulting from heavy concentrations of herded stock.

With the onset of the dry season this damage is greatly increased as the animals converge on the permanent water supplies. Development of additional water supplies has been a major task of the Conservation Authority. The sites are strictly limited by the nature of the geological structure. Two large dams, one large hafir and several boreholes and pipelines have been newly constructed. Allocations to Masai bomas, made with the object of dispersal of grazing, have been completely ignored and heavy stock concentrations overgraze the areas in succession.

The diversion of water from the Olmutoni Crater into pipelines to supply stock on the uplands grazing is believed to be at least a partial cause of the drying up of the hippo pool and marsh on the Crater floor.

The use of large grassland areas in the Eastern Plains, at present denied to the Masai by East Coast Fever, could be used if they would accept and use a dipping scheme. This they refuse to do.

Field Demonstration and Tour

The party visited the Ngorongoro Crater area, where a demonstration was given by Mr. and Mrs. Talbot of the weighing and measuring techniques in the field. A large Grant buck was collected by Mr. Mence for the exercise. Mr. Ledger of E.A.A.F.R.O. then joined Mr. Talbot in a demonstration of the carcass analysis techniques, while Dr. Brocklesby and Miss Walter of E.A.V.R.O. demonstrated collection of blood samples and tick samples.

The party then toured the Crater under the guidance of Mr. Mence, and examined pasture management problems. Much game was seen, although the familiar group of rhino did not appear on the Crater floor. One rhino was seen on the edge of the Oldeani bamboo, in which many are believed to reside. Mr. Fosbrook explained the meanings of Masai place names and described the early history of the Crater.

Acknowledgments

Thanks were expressed to Dr. Russell for his initiative in calling the Conference and for his expert chairmanship, to Major Bouker-Douglas of the Lake Manyara Hotel for the excellent arrangements made for over 50 members, and to the Tanganyika Game Department, National Parks and Conservation Authority for the field day arrangements.

THE INSECT PESTS OF AGRICULTURE IN THE COAST PROVINCE OF KENYA

V—MAIZE AND SORGHUM

By P. E. Wheatley, Entomologist, Department of Agriculture, Kenya

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Coastal Stem Borer (*Chilo zonellus*)

The adult is a night-flying, nondescript looking moth with a wing span of ¾ in. The larva is creamy pink with groups of dark brown spots along its back. The hooks on the false feet form a complete circle which is readily discernable under a hand lens, and it is on this character that the larva can be distinguished from the other main group of stem borers which include *Busseola* and *Sesamia*, where the hooks are arranged in a crescent.

Life History.—The eggs are very small, translucent white, scale-like, and are laid in groups of overlapping rows usually on the underside of the leaf near the midrib. They hatch in seven or eight days and the larvae migrate to the top of the plant where they tunnel in the leaf or midrib for several days before moving down the plant and enter the stem through the funnel, leaf midrib or from the outside of the stem. In older plants the whole life-cycle may be completed in the head or tassel. The larval stage lasts two to three weeks, and then pupation takes place in the stem. Seven or eight days later the adult emerges and makes its way to the outside to complete the life-cycle.

This species occurs over the whole province and is by far the most important stem borer of cereals. Some parasites are known, but they do not exert any appreciable control over the pest.

Damage.—The presence of stem borers in maize and sorghum is normally recognized by "windowing" and small yellow streaks on the leaves where the early larval stages have mined in the leaf and on occasions cut through it. The damage, however, is done when the larvae burrow down the stem, interfering with the normal physiological processes of the plant and weakening the stem. If attacked early in the season the maize plant or sorghum tillers will probably be killed, leaving a typical dead-heart, and if not killed the yield of grain is likely to be reduced. Malformation of the plant frequently occurs following stem borer attack. Damage to the developing maize cob is also fairly common.

The yield loss in maize from stem borers was assessed in experiments at Matuga, Malindi and Galole in 1957 and 1958 and varied from 23 per cent to 53 per cent of the crop. No assessments were made of losses in sorghum crops, but although sorghum usually carries much heavier infestations of stem borers than maize, the faculty of the crop in producing additional tillers to replace those killed by borers results in a much smaller yield loss than that suffered by maize.

Sesamia Calamistes

The adult is a fawn-coloured night-flying moth with a wing span of 1¼ in. Larvae are not dissimilar to those of *Chilo zonellus*, but can be readily distinguished from that species by studying the arrangement of the hooks on the false feet.

Life History.—Eggs are rounded, white turning to brown, and are laid in groups between the leaf sheath and the stem. The life-cycle in general is similar to that of *Chilo zonellus*, although the larval and pupal stages take a little longer. This species is not very common on the coastal plain, but fair numbers are found at Kalolani, Taveta and the Teita Hills.

Damage.—In general this is similar to that caused by *Chilo*, but there is more windowing and less mining of the leaves. The larva is more voracious and makes a greater mess of the stem. Damage to maize cobs or sorghum heads is not so common but does occur.

Stem Borers of Minor Importance

Chilotraea argyrolepia is, as far as we know, similar in all respects to *Chilo zonellus*. The larvae of the two species cannot be separated, although the adult *C. argyrolepia* has a golden margin to the fore wing which readily distinguishes it from *C. zonellus*. *C. argyrolepia* is never very abundant. *Cirphis loreyi* has been found boring maize at Galole, but is probably of no economic importance.

Busseola fusca.—This is the most important stem borer over wide areas of Africa, but in the Coast Province it is only found in the higher parts of the Teita Hills.

Control of Coastal Stem Borers

Chilo zonellus is by far the most important stem borer at the coast and fortunately control measures aimed against this species are effective against the other species occuring at the coast.

Chilo is not capable, as far as we know, of hibernating and depends for survival during the dry season upon finding hosts in which it can continue to breed. Although some wild grasses are very occasionally found to contain *Chilo,* by far the greatest proportion of the carry-over from one year to the next takes place in maize and sorghum residues left in the field from the short rains crops. It is, therefore, essential to destroy all sorghum stubble and maize stems during the dry seasons each year. If this is efficiently done, the initial infestation in the long rains crop is very low, and by the time large borer populations have built up, the crop will be past the most susceptible stage and will be more capable of withstanding attack. Burning is undoubtedly the most effective method of destroying crop residues, but feeding to cattle or deep burial is acceptable.

Early planting of main rains maize and sorghum is advocated so that the crop passes through the susceptible stage before the main seasonal build-up of borer takes place. The rogueing out and destruction of "dead-hearts" during the first month of growth will retard the rate of build-up and is recommended. Damage from stem borers is always more severe in short rains crops than those grown in the long rains.

Insecticidal control can be achieved on maize by spraying with 0.1 per cent D.D.T. emulsion to wet the leaves, but care must be taken to prevent excessive run-off of insecticide into the funnel for under certain conditions scorching will result. One application ten days after germination followed by a further one ten days later is normally sufficient, although a third application ten days after the second should be made when a heavy attack is expected. These insecticidal control measures are not recommended for sorghum, because the plant replaces damaged tillers, so that the final yield losses are never very high and spraying is unlikely to be an economic proposition.

Methods of applying D.D.T. dust to the funnel to control *Busseola* have proved disappointing for the control of *Chilo,* and are not recommended at the coast.

Heliothis bollworm (*Heliothis armigera*)

The caterpillar of this night-flying moth is variable in colour, normally pale olive green or straw brown. Bands of lighter and darker shades occur running longitudinally down the dorsal surface. This pest is most frequently seen on the cotton crop where it attacks the bolls, or on the fruits of tomato.

Adults migrate into the maize crop to lay eggs on the silks, and on hatching the larvae tunnel into the developing cob where they spend the remainder of their larval life. When full grown, they fall to the ground to pupate in the soil. The damage generally does not reduce yield to a great extent and specific control measures are not recommended. Damage to sorghum is comparatively rare.

Central Shoot Fly (*Atherigona indica*)

Adults lay eggs on young sorghum tillers near ground level. The larvae burrow into the central shoot of the tillers, which turn pale yellow or white and die. The damage results in the production of extra tillers by the sorghum plant, and this largely compensates for the damage done by the pest. Losses in yield following attack by central shoot fly are generally negligible in timely planted sorghum, but when late planted the crop may suffer moderate losses. Dusting around the base of the plant with 3:10:0 (D.D.T./B.H.C.) cotton dust gives good control if applied weekly commencing soon after germination and until the plants are 1 ft. high. Maize is not attacked.

Sorghum Midge (*Contarinia sorghicola*)

The adult midge lays eggs on individual grains soon after the sorghum panicle has emerged from its sheath. The larvae hatch and feed externally on the grain under the protection of the glume, leading to abortion of the grain. When squashed between thumb and forefinger an infested grain often shows an orange coloration; this is due to the presence under the glume of the midge larva which is bright orange when full grown.

Very little is known concerning the amount of damage occurring at the coast, and no control recommendations can be made. Maize is not attacked.

Maize Aphids (*Aphis maidis*)

These aphids are bottle-green and normally occur between the leaf bases and funnel of maize plants. In the drier areas they frequently build up high populations, especially towards the time of flowering and may lead to chlorosis of the central leaves. Black sooty mould may occur in association with the aphids. In extreme cases a reduction in yield undoubtedly occurs, but control measures are unlikely to prove economic in the majority of cases and are therefore not recommended.

Aphids occur on sorghum but are of little importance.

MINOR PESTS OF MAIZE AND SORGHUM

Several species of grasshoppers and leaf-eating weevils attack maize and sorghum. Weevils may invade the crop in large numbers very early in the season, in which case a spray of D.D.T. 25 per cent emulsion at three pints (plus water) per acre or 15 lb. of 5 per cent D.D.T. dust per acre should be applied. Grasshopper damage is rarely serious and no control measures are required.

A webbing caterpillar *Merasima trapezalis*, which attacks maize leaves, can be controlled in the same manner as leaf-eating weevils, but only in rare cases will the severity of attack justify this.

Rats and mice frequently remove maize and sorghum seed after planting but before germination. A seed dressing of 8 oz. of aldrin 40 per cent wettable powder per 100 lb. of seed should give adequate protection and is easy to apply. This seed dressing should be applied in any case, whether rats and mice are present or not, when dry planting is undertaken.

PRELIMINARY OBSERVATIONS ON THE POPULATION DYNAMICS OF THE WILDEBEEST IN NAROK DISTRICT, KENYA

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(*Received for publication on 7th April, 1961*)

Effective wildlife management must be based on knowledge of the population dynamics of the species involved. The type of information needed by the wildlife manager is not essentially different from that required by a cattle rancher. Both must know, for example, the size of their animal population, the ratio of males to females, young to adults, age of reproduction, rate of reproduction, rates of mortality, and causes of mortality. Knowledge of food habits is also essential, but it does not come under the heading of population dynamics. Preliminary food habit findings of this study are the subject of a separate paper (Talbot, 1961).

In recent months much official consideration has been given to wildlife management in the Mara region in Narok District, Kenya. From the standpoints of contact with domestic livestock, migrations, and relationships with predators and other herbivores, the wildebeest is probably the most important single herbivore involved. However, very few data have been available on the population dyanmics of this species in East Africa.

The present long-term ecological study of plainsland and plains wildlife was initiated by the author on the Serengeti Plains in January, 1956, and the current field work began in July, 1959. The study is still in progress (February, 1961), and it will be some months before the field and laboratory data collected are analysed and the final results are presented. However, since there is an immediate need for information on wildlife population dynamics for management purposes, this paper is presented to provide some of that information at the time it is needed. This paper presents in summary form preliminary observations on the population dynamics of the wildebeest in Narok District. The basic principles should apply equally to wildebeest in adjoining areas.

The Wildlife Research Project has been financed jointly by the Foreign Field Research Programme of the United States National Academy of Sciences-National Research Council, the New York Zoological Society, and the Government of Kenya. We wish to express our appreciation to the Kenya Game Department and the Kenya Veterinary Department, with whom we have worked closely throughout this project and whose friendly co-operation and aid have made this work possible; and to the East African Agriculture and Forestry Research Organization and the East African Veterinary Research Organization for facilities, equipment, and other forms of aid.

METHODS

Study Area.—The area involved is the total area over which the wildebeest pass during their yearlong movements. In Tanganyika it includes the area bounded on the east by the Rift wall, the south by the southern end of the Serengeti Plains above Lake Eyasi, and on the west by Lake Victoria. In Kenya, the Rift is again the eastern boundary, the Mau escarpment is the northern edge, and the Siria Escarpment the western boundary of wildebeest movement. This paper is concerned primarily with the Kenya region.

Field Techniques.—The two primary sources of data have been systematic observation and animal collections. Much valuable data has been collected from detailed, prolonged observation of individuals and herds while the observer remained in one spot. However, since the study area is very large, much use has been made of strip sample counts and observations, reconnaissances, and by vehicle and by aircraft. The results of these have been checked by total counts and surveys.

Collections have been made of wildebeest throughout the year. The animals collected have provided a variety of data including information on weights, growth rates, condition, parasites, diseases, food, and reproduction. Most of the animals have been collected at random, to provide a random sample of ages and sexes. Some individuals have been picked

for collection, for example, young animals at monthly intervals to provide a series of known-aged skulls from which ageing criteria has been determined.

Most animals have been collected by the author with a shot in the neck vertebrae which drops the animal instantly. The rifle used is a telescope-sighted .308, a high-velocity, flat-trajectory rifle which allows precision shooting at considerable ranges, to avoid undue disturbance of other animals. Usually, during each collection a team of specialists from the Kenya Veterinary Department, East African Veterinary Research Organization, or East African Agriculture and Forestry Research Organization has joined the Wildlife Research Project. Therefore, each animal collected at these times has been subjected to exhaustive examination and analysis.

A further series of animals has been examined while they were immobilized (Talbot, 1960; Talbot and Lamprey, 1961). After examination, these animals have been marked and released, and their movements subsequently followed. Marking has been by means of metal or plastic ear tags, coloured strips of plastic attached to ears, paint, and bobbed tails and beards. By using various colour combinations in the plastic ear strips, after release individual animals can be identified from distances of over 100 yd. by binoculars. The plastic used was commercial P.V.C. in strips up to about 8 in. long and in widths varying from ½ in. to 2½ in. These strips were attached to the ears by rivet-type ear-tags or tied through the ear by a jesse knot. Some of the ear markings have remained in place and identifiable for over a year, throughout the period of observation to date. The bobbed tails facilitate initial location of marked animals from aircraft or from considerable distances on the ground. Paint on horns and on the animal's back wears off after a period of two to three weeks, but greatly facilitates tracing the animal's movements during that period. The marked animals have provided particularly valuable data.

Results

Age.—Preliminary criteria have been established which allow close age determination from birth to about four years of age, and which define three age stages beyond that point. Detailed description and analysis of these criteria will be presented elsewhere. The criteria are based on a correlation of factors including tooth erruption and wear, body and horn size, weight and conformation, and season of collection (since wildebeest have a fairly regular period of calving (*see* below)).

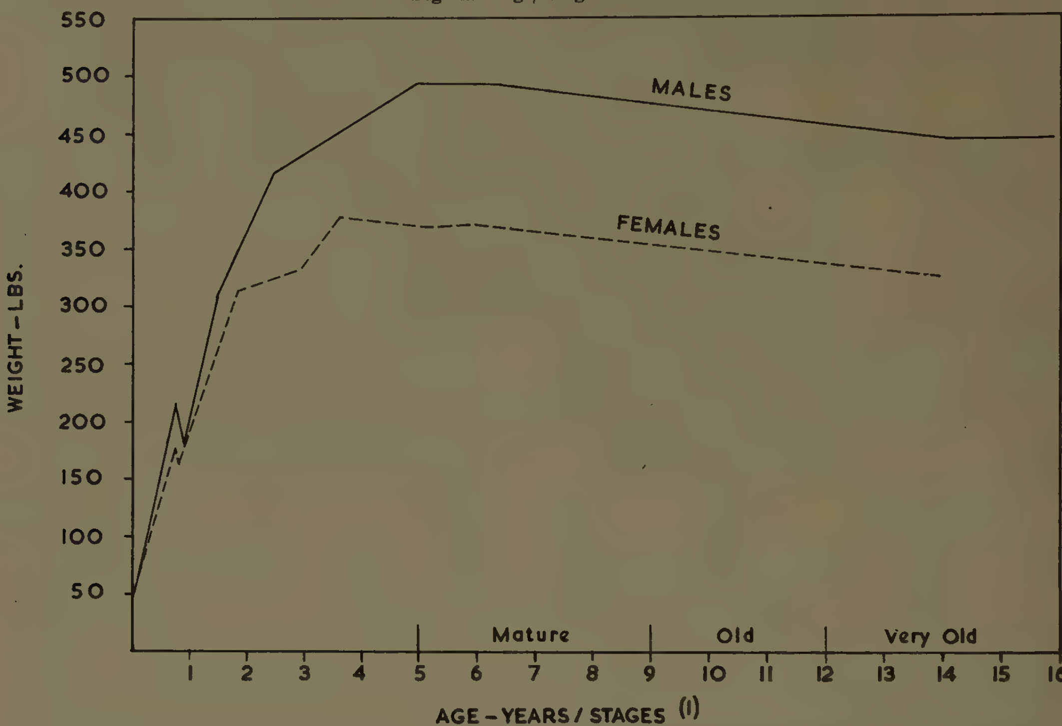
Beyond four years of age three stages are recognized: mature, old, and very old. There are no longevity records directly from wild wildebeest populations. The maximum longevity of the wildebeest in zoological gardens is 16 years (Bourlière, 1955). Maximum longevity is rarely achieved in a wild animal. Therefore, although an occasional wild individual may live to the maximum age of captivity, 14 years is probably nearer the actual maximum age in the wild. The ages from about 4 to 14 years have been divided provisionally into the three recognizable age stages. Thus, a *mature* animal is roughly between 5 and 9 years, and an *old* one between 9 and 12, and a *very old* one over 12.

Weight.—To date (February, 1961) 130 wildebeest of all ages have been weighed. The age of the weighed animals has been determined, as above, and Figure 1 gives the resultant age/weight chart. Growth is interrupted at about ten months by the "yearling diesease" which strikes virtually all yearlings in the Narok District wildebeest population. The female growth rate follows a step-like pattern which appears to be correlated with periods of pregnancy. After the period of maximum growth is reached, at roughtly five years, there is a slow but steady decline in weight through the rest of life.

Reproduction.—Wildebeest young are born between mid-November and mid-May. Most calves are dropped from January through March. The gestation period appears to be roughly nine months. Most (86 per cent of the sample) females are bred when just over one year old, so that the first calf is dropped when they are about two years old. Cows normally have a calf a year after that through old age. One hundred per cent of all cows examined from age two through the *old* stage (provisionally about 12 years old) were pregnant or had dropped a calf that season. The only fully adult non-pregnant cows examined were very old, provisionally over 12 years of age. In terms of the total female wildebeest population of breeding age, over 95 per cent of the females produce a calf each year. No definite evidence of twins has been noted.

The calf is nursed until next year's calf is born, and if the new calf is lost, the older one apparently resumes nursing until at least 16 months of age. The milk is only a supplement, however, for young wildebeest start eating grass when

Fig. 1.—Age/Weight Chart

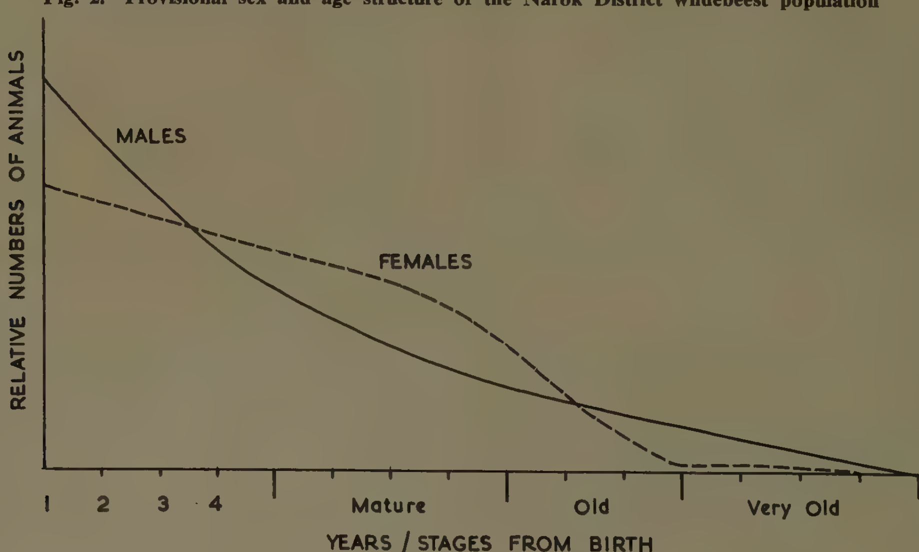


([1]) Beyond years 4-5 age stages are recognized, and years assigned provisionally on the basis of a maximum probable age of 14.

about ten days old, and grass makes up the bulk of their diet when about three months old.

Adult Mortality.—The age/sex structure of the wildebeest population is shown in Figure 2. After adult males reach the mature age stage, mortality is relatively evenly distributed throughout their lifespan, and a random sample of adult males shows virtually as many very old males as those in the other two age classes. Females, on the other hand, incur most of their mortality during their reproductive

Fig. 2.—Provisional sex and age structure of the Narok District wildebeest population



life. Only 2 per cent of the females who live past their first year survive beyond the old age stage. Reproduction is probably the reason for this disparity in mortality effects. Females which are heavily pregnant, are giving birth, or protecting their young, are more vulnerable to predation and disease than males.

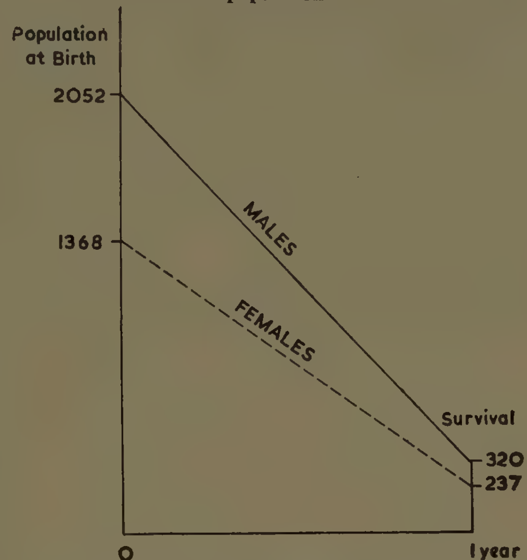
The primary known cause of adult mortality is predation. There are between 200 and 300 lions in the Narok District (Temple-Boreham, verbal; records of this study). In a study of predation in the Serengeti National Park and the Nairobi Park, Wright (1960) stated that the average annual kill per lion was 36.5 individuals of the major prey species. In Narok District the annual average prey kill per lion appears to be about 35 (this study). Wright (*ibid.*) found that wildebeest made up about half (49 per cent) of the lion kills, and this figure agrees with the present findings in Narok District. At this rate, between 3,500 and 5,250 wildebeest are lost yearly to lion alone. Added to this loss is predation by leopard, cheetah, hunting dogs and hyena, all of which prey to some extent on wildebeest (this study; Wright, 1960; Temple-Boreham, verbal). A conservative estimate of the yearly wildebeest predation loss, based on the above figures and observational evidence, is 4,000 animals. Of these, on the same basis, roughly 1,500 are young animals and 2,500 adults. The adult wildebeest kill appears to be about 1,100 females and 1,400 males.

Calf Mortality.—(Figure 3) On the basis of the samples collected, there is no demonstrable mortality between conception and birth. During the first two weeks after birth a large percentage of calves die or are killed. This loss is due in part to predation, especially from hyenas; and part to disturbance of the herds which results in the young animals becoming separated from their mothers. This latter factor is especially important in very large herds. The lost calves wander about from wildebeest to wildebeest, and are roughly shoved away by both bulls and cows, eventually to die of starvation or, more likely, to be eaten by predators.

Following the first month of life, there is a steady loss of calves to predators, at a level much lower than that of the first month. During the past two growing seasons in Narok District, the annual predator kill of yearling wildebeest has amounted to about 45 per cent of the total calf crop.

The other principal known source of calf mortality is disease. Starting in October or

Fig. 3.—Calf mortality during the first year of life calculated for Narok District wildebeest population



November, usually following the short rains and a flush of green grass, numbers of seven to ten-month-old wildebeest calves are noted to be sick or dying. This condition continues in greater or lesser intensity through January, by which time about 40 per cent of the total initial calf crop has succumbed figure based on periodic censuses, age counts, and carcass counts and examinations). Virtually all calves observed have been affected in some degree.

The E.A.V.R.O. personnel who have examined some of the sick animals believe that the disease is rinderpest (Plowright and Ferris, 1961). It appears that the new-born calves have a chloesterol immunity to this disease which they have received from their mothers. The initial immunity presumably wears off after roughly five to eight months, leaving the calves suceptible to rinderpest. Apparently, the animals are exposed to the disease about the time that their resistance is drastically lowered, through prolonged drought, extended migration, and/or the short rain induced flush of green grass. The combination of these factors, probably plus others (including predation on the weakened animals), brings about a high mortality. Those animals which survive have presumably acquired an immunity to rinderpest.

During the past two years the combination of disease and predation during the first year appear to have reduced the annual calf production by 85 per cent.

Sex Ratio.—The foetal sex ratio, which is apparently the sex ratio at birth, is 40 per cent females to 60 per cent males. After the first year of life the sex ratio is 42 per cent females to 58 per cent males. The overall sex ratio of adult wildebeest is 45 per cent females to 55 per cent males. Therefore, although there are more males than females in the total population, from birth to maturity there is a differential mortality in favour of female survival.

Size and Structure of Population.—The 1959-60 wildebeest population in the Narok District was roughly 7,000 to 8,000 animals (Grimwood, 1960; this study). Its population structure is diagrammed in Figure 4.

The age and sex structure of the known annual mortality is diagrammed in Figure 5. It can be seen from a comparison of these two figures that with the wildebeest population at its 1959/60 level, the population increase could not balance the decrease due to mortality. If mortality factors remained constant, i.e. predation at the present level and disease taking 40 per cent of the annual calf crop, an adult population of about 16,220 would be required to balance the known mortality (Figure 6).

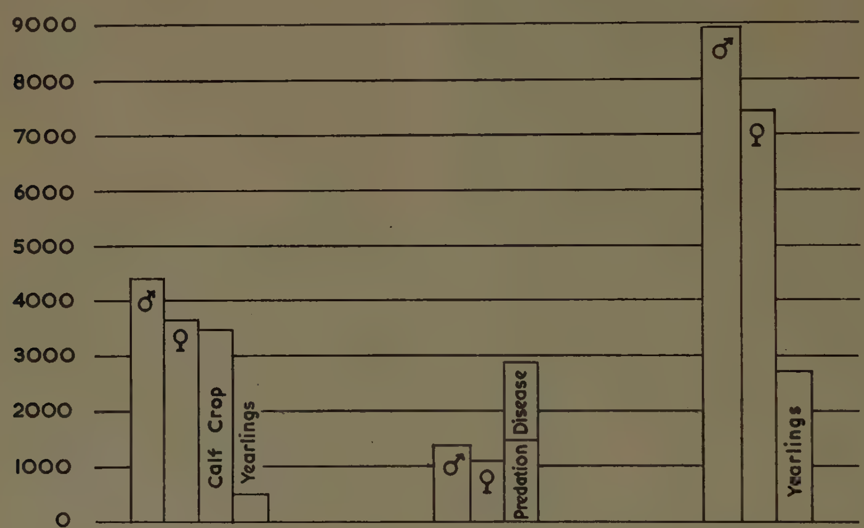


Figure 4

Structure of 1959-1960 wildebeest population in Narok District

Figure 5

Source and age/sex distribution of known present mortality

Figure 6

Estimated population required to balance current levels of predation and sickness: 16,220

To check the accuracy of the above calculations, one can compare the 1959/60 population with that counted in the course of Dr. Darling's ecological reconnaissance of the Mara in 1958. Darling (1960) records a total of 16,985 wildebeest from the Mara and the immediately adjoining plains in Tanganyika. He estimates (*ibid.*) the total in the Mara area alone at 15,000. In the course of the present study at least part of the "Tanganyika wildebeest population" has been observed to enter Kenya and join the "Kenya population", and vice versa. Consequently, we have taken the effective Kenya population at that time to be between Darling's two figures, and to facilitate calculations, called it 15,725. If mortality and reproduction rates remained constant, and no other source of population loss existed the wildebeest population should have decreased from 15,725 in October-November, 1958, to 13,043 in October-November, 1960 (Figures 7 and 8). This reduction would represent a loss of some 17 per cent of the initial total in two years. However, the actual census figures from this study show that the wildebeest population in October-November, 1960, was roughly 7,000 (Figure 9), which represents a loss of 55 per cent in two years.

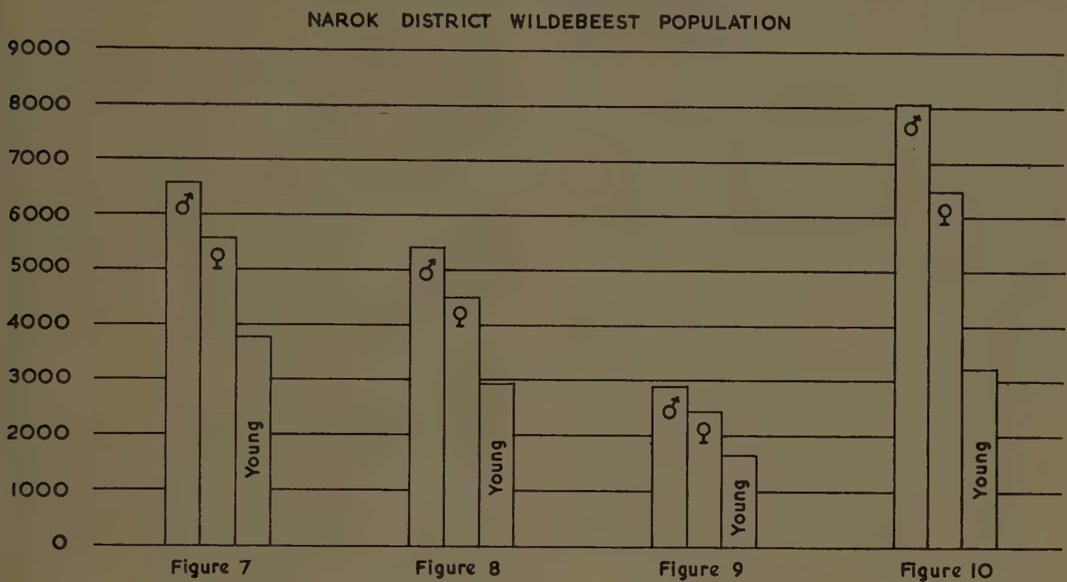


Figure 7	Figure 8	Figure 9	Figure 10
Oct.-Nov., 1958	**Oct.-Nov., 1960**	**Oct.-Nov., 1960**	**May, 1961**
15-16,000	**c. 13,000**	**c. 7,000**	**c. 17,800**
Count(1)	**Calculation(1)**	**Actual population**	**Actual population**

(1) Population structure and decline based on:—

1. 1958 total population from Darling (1960).
2. Adult sex ratio of 45 females to 55 males.
3. Yearling sex ratio of 42 females to 48 males.
4. Adult female birth rate of 95 per cent.
5. Yearly predation remains constant at 4,000 animals, of which 1,500 are calves, 1,400 adult males, 1,100 adult females.
6. Disease kills 40 per cent of annual calf crop.
7. No other source of loss or mortality.

Mortality factors in addition to predation and disease include legal and illegal hunting, and accidents. The observed losses from these causes are not high enough to account for the figure of 55 per cent. The remaining known source of wildebeest population loss is emigration. From the preliminary analysis of the data it appears that most of the population loss, over and above the loss expected from predation and disease, is due to movement of the population out of the Narok District study area*.

Population Movement.—Although population movement or migration is not properly a part of population dynamics, in the present case it vitally affects the Narok District wildebeest population size and structure. Wildebeest migration is also of vital concern from the standpoint of wildlife management, both in Kenya and Tankanyika. Consequently a very brief outline of migration factors is included below.

In general pattern, the wildebeest herds spend the dry season near available water, usually in the south-west area of the Kenya Mara region, or across the border in the Tanganyika Mara or the northern extension of the Serengeti National Park. In the wet season they move north and east. There is no orderly or regular migration such as is observed in birds, but rather the picture is of an eddying and flowing, sometimes concentrated and sometimes dispersed. A detailed discussion of the factors involved in wildebeest migration will be the subject of a subsequent paper, but the two primary factors (as presented by the

* In late May, 1961, an aerial census of the Narok District showed a wildebeest population of 17,817, plus a significant number of wildebeest in the adjoining portions of Tanganyika (Stewart and Talbot, 1961).

author at the Conference held in Arusha, 11th and 12th May, 1960, on Research Problems in the Serengeti National Park) appear to be grass—species composition and stage of growth as determined by rainfall, fire and grazing—and surface water.

Wildebeest display a marked preference for short (under 4 in. high) fresh green grass (Talbot, 1961), and throughout this study the wildebeest have been observed on, or moving in the direction of areas of available short, green grass usually in the proximity of surface water, or areas where it was raining or where rain had fallen within the past 24 hours. Herds travel long distances in the direction of rainstorms. Since these movements may be up, down, or across the prevailing winds, and they are observed at all seasons and under widely varying conditions of temperature and humidity, it is probable that the primary stimuli for these major herd movements are visual. The sense of hearing may also be involved, as thunder often accompanies the isolated rainstorms toward which herds are observed to travel.

Twice in the past year aggregations of up to 3,000 wildebeest moved from the Mara River or Talek region of Narok District up across the Bardamit Plains to the Loita Plains at periods when the Loita and Bardamit areas were extremely dry. These movements coincided with very heavy thunder and rainstorms near the Loita, which appeared to be on the Loita Plains, and which could be seen and heard by observers who were with the wildebeest at that time. The rain had actually fallen not on the plains, but on the nearby wooded hills. In both cases the animals milled about on the dry plains for about two days, with no water and apparently no suitable food. Then they returned the way they had come, moving at a steady trot to the well-watered vicinity of the Mara and Talek Rivers. The total distance covered in these apparently futile round trips was roughly 120 miles.

As long as short green grass is available the wildebeest will follow and feed on it. The habits and life-cycle of the wildebeest appear to be strongly oriented around the availability of and search for new green grass. For example, the location of calving appears to be determined primarily by grass growth and water. During the past two seasons nearly as many calves have been dropped in the other parts of the Narok District as on the Loita Plains, the traditional "wildebeest calving ground." From the results to date of the present study, there is no indication that access to the Loita Plains for calving is essential for the survival of the wildebeest. If the animals were denied access to that area for management reasons, for instance, by construction of a game fence, maintenance of the wildebeest population should be unaffected *as long as sufficient, acceptable food and water were to be found in their remaining available range.* This principle should hold true with the Serengeti wildebeest, if a game fence were to be constructed to keep the wildebeest within the park boundaries.

Local, small-scale, herd movements appear associated with muddy ground and movements of other herds. The grazing patterns observed on various plains areas appear correlated initially not with the species of grass present, where this has been constant, but rather with the available grasses that were growing on the driest footing. As postulated by Dr. H. Heady (Heady, 1959, verbal) and subsequently confirmed by the present study, wildebeest and many other wild species markedly avoid muddy "black cotton" soil wherever possible.

Movement and proximity of other wildebeest herds also appears to influence individual wildebeest movements. Individual animals or small herds have often been observed to leave an area occupied for some weeks, or to alter their own direction of movement, in order to join a larger "migrating" herd.

This follow-the-group behaviour may explain the recent fluctuations in the numbers of Narok District wildebeest. During August and September, 1960, thousands of wildebeest and associated animals from the Serengeti Plains migrated northward moving through the western edge of the northern extension of the Serengeti Park. These animals travelled from the Western Corridor section of the park to the Talek Plains area in Kenya. The northern migration route of a part of the population, followed by Land-Rover, covered 137 miles starting from the National Park boundary on the Western Corridor. The animals vacated the dry Central Plains and Corridor, and moved through the often dense brush following the areas which had been recently burned and rained upon, and which were carpeted with a flush growth of short green grass. For a period of four to six weeks these animals mingled with a part of the "Kenya wildebeest population", the wildebeest and associated species—particularly zebra,

Thomson's gazelle and topi—concentrating on the Egolok and Talek Plains of Kenya and the plainsland near Kuka Mountain and the Bologonja River in Tanganyika, where grass fires followed by rain had produced a flush of grass. During late September and October the northern plains areas became dry and the bulk of these animals moved south, through the central and eastern portion of the northern extension of the Serengeti Park. Presumably, these animals were accompanied by some of the animals "resident" in Kenya during the previous months. No marked wildebeest were observed in this movement south, but one topi marked in Kenya was subsequently observed in the Serengeti National Park. This specimen, a female, was marked near the Governor's Camp on the Mara River on 17th July, 1960. She was sighted the following day, and was next seen (at close range by several observers) with a young calf at heel at Seronera Camp in the first week of November (Mathews, 1961; G. Poolman, verbal). Only one topi has been marked in Tanganyika, a male, with different coloured ear tags from this marked female. Since the animal was marked one and a half months before the arrival in Kenya of the animals migrating north from the Serengeti, and was sighted at Seronera (roughly 120 miles south) after the return there of the "northern migration", it appears that this topi joined or followed the large herds from the Serengeti when they moved back south. From observation and counts, it appears that the same thing may have happened with a significant number of the wildebeest present in the Talek-Egolok area before the influx of the southern herds. This interterritorial exchange of animals may be a frequent but irregular occurrence, with the direction and magnitude of movement determined by the patterns of rainfall, grazing and grass burning.

Subsequent to the October-November census in the Narok District, a second "migration" of wildebeest occurred, the animals again moving north from the Serengeti Plains and Corridor region. This movement occurred at the same time as the peak of the yearling die-off in the Serengeti region, and the migration path was littered with hundreds of yearling carcasses. These animals followed the same route as the August-September movement, entering Kenya in late November and December*.

Conclusions

From the foregoing, brief summary of the preliminary observations on population dynamics of the wildebeest in Narok District, the following conclusions may be drawn:—

1. The wildebeest have a very high reproductive rate. Over 95 per cent of all females of breeding age produce one calf each year.
2. The mortality rate of wildebeest is extremely high. At the current rate, the combination of predation and disease annually remove such a large proportion of the wildebeest that a population level of over twice the 1959/60 numbers would be required to achieve a high enough survival rate of young animals to maintain a population equilibrium.
3. The population loss (55 per cent) between 1958 and 1959 is too great to be accounted for purely by predation and disease. Much of the loss appears to result from movement of animals south into Tanganyika*.
4. The wildebeest population movements appear to be determined by grass growth, which is a function of burning, grazing and rainfall; and availability of water. The location of calving appears to be determined by these factors, and there is no indication that access to the Loita Plains is essential to wildebeest reproduction or survival, so long as adequate acceptable food and water exists elsewhere in their range.
5. Because of the interterritorial movements of the animals apparently following the changing distribution of their preferred grass foods and water, from the standpoint of population dynamics, ecological research and applied management, the region of the Serengeti National Park and the adjoining portion of the Narok District of Kenya are not separate entities and should be considered as a single ecological unit.

* Although a return migration to the Serengeti Plains was observed, roughly 10,000 of these animals remained in Kenya, as shown by the count of over 17,000 wildebeest in May, 1961 (Stewart and Talbot, 1961).

* The May, 1961, wildlife census showing an increase of about 140 per cent over the 1960 population (Figure 10) proves the existence of an irregular exchange of population between Kenya and Tanganyika.

REFERENCES

Bourliére, F. (1955). *The natural history of mammals.* Harrap, London. 363 pages (page 202).

Darling, F. F. (1960). An ecological reconnaissance of the Mara Plains in Kenya Colony. *Wildl. Monographs,* No. 5. 41 pages.

Grimwood, I. (1960). Report of an aerial count of game in the Loita Plains. Kenya Game Department. Typed. Ref. GA 3/1/8/8.

Mathews, T. (1961). Personal correspondence dated 7th January, 1961.

Plowright, W., and Ferris, R. D. (1961). Serological evidence for enzootic rinderpest in wildebeest of the Serengeti-Mara-Loita Plains area. Paper for Conference on Land Use Problems in Areas Containing Game, Lake Manyara, Tanganyika. Two pages. (Mimeo.)

Stewart, D. R. M., and Talbot, L. M. (1961). Aerial census of the Serengeti-Mara-Loita Plains. Kenya Game Department. Ref. GA 3/1/8/8. (Mimeo.)

Talbot, L. M. (1960). Field immobilization of some East African wild animals and cattle—I. *E. Afr. agric. and for. J.* 26(2):92-102.

Talbot, L. M. (1961). Preliminary findings on food preferences of some East African wild ungulates. *E. Afr. agric. and for. J.* (In press.)

Talbot, L. M., and Lamprey, H. F. (1961) Immobilization of free-ranging East African wild ungulates with succinylcholine chloride. *J. Wildl. Mgmt.* 25(3):303-310.

Wright, B. S. (1960). Predation on big game in East Africa. *J. Wildl. Mgmt.* 24(1):1-15.

REVIEW

DIGESTIVE PHYSIOLOGY AND NUTRITION OF THE RUMINANT, edited by D. Lewis, published by Butterworths, London, 1961, pp. 276. Price Sh. 50.

The Seventh Easter School in Agricultural Science held at the University of Nottingham School of Agriculture in April, 1960, discussed the contribution made by the rumen to the nutrition of the ruminant, and this book is a record of the proceedings of the Conference.

It is arranged in three parts: Part I is concerned with the physiology of the rumen, Part II with metabolism in the rumen, and Part III with ruminant nutrition and endocrinology. Contributions to each part are made by well-known authorities and discussions on their respective subjects are recorded and grouped appropriately throughout the text. The result is a pleasing, comprehensive and well documented account of the many aspects of rumen behaviour.

This book will be of great assistance to teachers, research workers and students of animal nutrition. It cannot be expected to have the same appeal to those who are engaged in advisory work and who may wonder how much of the detail concerning but one important organ of the alimentary tract can usefully be applied to the resolution of everyday nutritional problems of economic importance.

H. W. D.

NEMATOCERUS sp. (nr. brevicornis Hust.)—A PEST OF CEREALS IN KENYA

II—THE EFFECT OF INSECTICIDES ON THE OVA

By J. A. Bullock, Entomologist, Department of Agriculture, Kenya

(*Received for publication on 20th March, 1961*)

The ova of *Nematocerus* sp. (nr. *brevicornis* Hust.) are usually laid on leaves of cereals or other Gramineae in a fold made by the female weevil [1]. Although the fold is sealed with a layer of adhesive secreted by the abdomen of the female, there was a possibility that the application of insecticide would cause heavy mortality in the egg mass and, since control of the larvae presented considerable difficulties, such a possibility was obviously worthy of test. To this end, four laboratory tests were conducted and subsequently one small and one large field trials were laid down.

Laboratory Tests

In all tests the egg masses were collected in the field and were examined to select only those masses in which the adhesive layer appeared intact. The masses were then subject to the prescribed treatment and placed in receptacles until such time as emergence from the leaf was complete. The numbers of emerged larvae were then counted, and each egg mass was opened and the numbers of ova, and of larvae remaining within the fold, recorded.

Test 1.—Ten egg masses in their leaves were dipped in 0.1 per cent insecticidal solutions and then placed in petri dishes on black filter paper. The egg masses were kept moist and examined daily until emergence ceased on the fourteenth day. Counts were then made and the results (Table 1) indicated that gamma B.H.C. offered the best prospect of control.

Table 1

(1 × 10 *egg masses per treatment*)

Insecticide (0·1%)	No. of larvae emerged	No. of ova remaining	No. of larvae in the fold	Percentage emergence
gamma B.H.C.	1	149	2	0·66
Rogor	22	53	27	21·57
Metasystox	55	51	31	40·15
Control 1	44	27	33	42·31
Heptachlor	85	48	31	51·83
Dieldrin	43	26	0	62·32
D.D.T.	72	10	9	79·12
Control 2	134	17	4	86·45

Test 2.—Aqueous solutions containing 0.25 per cent, 0.125 per cent, 0.0625 per cent and 0.03125 per cent gamma B.H.C. were prepared and 25 leaves containing eggs were dipped in each concentration. A further 25 were dipped in distilled water. The masses were laid on a glass plate and left for four hours to dry after which they were placed in 3-in. × 1-in. tubes five at a time and left unstoppered for 14 days by which time emeregence had ceased. The tubes were "watered" regularly, to avoid excessive drying out. After 14 days, each tube was examined, the emerged larvae counted, and the egg masses opened to discover the numbers of ova and of larvae remaining in the fold. A record of the number of Chalcids present was also kept.

The results (Table 2) show that all concentrations of gamma B.H.C. had prevented emergence from the leaf. Within the leaf fold a fairly large number of larvae had hatched in the lower concentrations, but had failed to exit.

The reduction in the number of Hymenoptera present is inconclusive, but suggests that gamma B.H.C. affects them adversely.

Table 2

(5 × 5 *egg masses*)

Concentration	No. of larva emerged	Percentage emerged	No. of ova remaining	No. of larvae within	No. of Chalcids
%					
0	291	83·1	66	3	8
0·03125	1	0·24	275	145	4
0·0625	0	0	384	86	3
0·125	0	0	391	52	3
0·25	0	0	452	10	0

Test 3.—Five egg masses were placed in each of six 3-in. × 1-in. tubes. Pieces of filterpaper were soaked in 20 per cent gamma B.H.C., air dried, and placed in four of these tubes in such a way that they touched none of the

masses. After six hours, the papers were removed and the tubes recorked. The remaining two tubes were kept as controls.

Fourteen days after the ova were collected (ten after treatment), the tubes were examined and the numbers of emerged larvae, and of ova and larvae remaining in the fold, recorded. The results (Table 3) are confused by the failure of one of the controls in which only 4.5 per cent emergence occurred, but suggest that gamma B.H.C. exerts a considerable fumigant action.

TABLE 3

(*Mean nos. per replicate*)

	No. of larvae	Percentage emerged	No. of ova remaining	No. of larvae remaining	No. of Chalcids
Treated	0·25	1·45	84·75	22·25	1·0 (0·5 sick)
Control	17·0	41·95	35·5	0·5	2·5 (0·5 dead)

Test 4.—Although D.D.T. had not appeared satisfactory in Test 1 a further test was performed because D.D.T. has been widely used for the control of adult weevils and because the usual concentration used is five times that used in Test 1 (i.e. 1 lb. in 20 gal. (0.5 per cent) as opposed to 1 lb. in 100 gal. (0.1 per cent)). The procedure followed was the same as that used in Test 2 with gamma B.H.C., using test concentrations of 1.0 per cent, 0.5 per cent, 0.25 per cent and 0.125 per cent D.D.T. The results (Table 4) whilst less impressive than those for gamma B.H.C. (cf. Table 2), show a greatly reduced emergence and also a reduction in the numbers of Hymenoptera.

TABLE 4

(5 × 5 *egg masses*)

Concentration D.D.T. %	No. of larvae emerged	Percentage emerged	No. of ova remaining	No. of larvae remaining	No. of Chalcids
0	267	79·5	47	22	9
0·125	94	28·7	184	50	2
0·25	95	27·4	173	74	3
0·5	46	14·4	213	60	1
1·0	25	6·9	308	28	0

As a result of these tests, it was concluded that both gamma B.H.C. and, to a lesser degree, D.D.T. were worthy of further testing.

FIELD TRIALS

Test 1.—Gamma B.H.C. was applied to young wheat as a 0.25 per cent solution at a rate of 50 gal. per acre (i.e. 20 oz. active gamma B.H.C. per acre) through a manual knapsack sprayer equipped with a three-jet boom. Thirty egg masses were collected after spraying and were examined after 14 days. The results (Table 5) serve to confirm the laboratory findings.

TABLE 5

Treatment	No. of emerged larvae	Percentage emerged	No. of ova remaining	No. of larvae within fold
0·25% gamma B.H.C.	14	2·7	464	39

Test 2.—Heavy oviposition occurred in a field of young wheat at Naro Moru in November, 1960, and an experiment was laid down to test the effect of gamma B.H.C., D.D.T., dieldrin and pyrethrum at various rates of application (Table 6). The sprays were applied with a pneumatic knapsack sprayer equipped with a three-jet boom, to single plots of 1/70 acre each. The rate of application was calculated to be just under 30 gal. of spray solution per acre at a pressure of 30 lb. per sq. in., and this gave a good visual cover.

One hundred and fifty egg masses were collected from each plot, as soon as the spray solution had dried, and these were placed in glass jars and brought back to the laboratory, where they were set up in 3-in. × 1-in. specimen tubes, 25 masses being allocated to each of six replicates. Hatching began on the eighth day after spraying, and on this date the site was revisited and a further series of 75 egg masses was collected from each plot. These were again set up in 3-in. × 1-in. tubes, 15 egg masses being allocated to each of five replicates. Throughout the test care was taken that

no contamination by foreign matter occurred and, for this reason, no attempt was made to check the growth of fungi which occurred to a disproportionate degree in the controls of the first series. This appeared to cause an increased mortality in all replicates of the control, whilst the lesser growth in other treatments had no effect.

The results were assessed by counts of larvae and by subsequent examination of the contents of the folds to give an independent check on mortality. The results (Tables 7 and 8) are expressed as mean emergence and mortality per egg mass, since despite care in sorting, some variability in numbers of masses occurred due to more than one mass being laid on a leaf.

The results show that considerable mortality occurred in the two high rates of gamma B.H.C. in the first series, but that no treatment produced any effect in those masses collected eight days after spraying. Emergence takes some 14 days from the date of oviposition and therefore it is reasonable to consider that a fair proportion of the masses collected in the second series were present during spraying and hence that at least a diminution in emergence might be expected even if the persistence of B.H.C. was very short. This was confirmed by the counts of larvae of which more than 50 per cent had emerged within three days of collection (11 after spraying) as compared with a 50-60 per cent emergence between the eleventh and twelfth days in the first series. Emergence continued up to the fifteenth day on the first series and for a little longer in the second. This result therefore implies that B.H.C. is toxic to the ova only in the vapour phase, as was suggested by the laboratory test 3, the effect only occurring when egg masses are removed to the laboratory whilst a heavy residue of insecticide is present.

Conclusions

Despite the early success in control both in the laboratory and in the first field trial, the result of the second field trial clearly demonstrates that control of the ova is not a feasible proposition with the insecticides tested. The success of gamma B.H.C. in the laboratory is attributable to the vapour phase penetrating the protective adhesive and its failure in the field to the dissipation of vapour. In the same way, the success of the D.D.T. treatment may be due to a vapour phase, the failure of the field spray even in leaves collected soon after treatment being due to the low concentration of the insecticidal deposit. This hypothesis is confirmed by the B.H.C. treatments in field test 2, where only the highest concentration (0.5 per cent) gave a kill approaching that of the least (0.03125 per cent) in the laboratory (test 2).

There is a possibility that other insecticides may give a control, but this is doubtful. The systemic organo-phosphorus compounds exert their effect on phytophagous insects as stomach poisons and it seems improbable that sufficient vapour would be generated in the leaf fold to influence mortality, whilst other contact poisons will suffer the same disadvantage that has already been encountered in the hydrocarbons tested. The possibility that the larvae might be controlled at the time of emergence is also remote as the newly hatched larvae are tolerant of the majority of insecticides (e.g. dieldrin, endrin, heptachlor, toxaphene) (unpublished work) which might be expected to persist through the period of emergence.

Summary

Laboratory tests with a number of insecticides indicated that gamma B.H.C. at low dilutions caused heavy mortality in the laboratory. An indication that mortality was due to the vapour phase of gamma B.H.C. was obtained.

In field tests, gamma B.H.C. caused high mortality in ova collected shortly after spraying, but not in ova collected eight days later, whilst D.D.T., dieldrin and pyrethrum had no effect.

It is concluded that the prospect of controlling *Nematocerus* through the ova or the newly hatched larvae is not promising.

Acknowledgements

I have to acknowledge the assistance of Messrs. H. G. Prettejohn and J. Thrane in field test 2, whilst a considerable amount of the routine laboratory counts were performed by Messrs. M. M. Katala, P. K. Nderi, I. Kasimu and J. N. Wainaina.

Reference

[1] J. A. Bullock. *E. Afr. agric for. J.*, 1961.

TABLE 6

Insecticide	Formulation	Concentration	Equivalent per Acre: of active ingredient	Equivalent per Acre: of formulation
		%	oz.	
B.H.C.	20% gamma	0·03125	1·5	7·5 oz.
		0·0625	3·0	15·0 oz.
		0·125	6·0	1·5 pt.
		0·25	12·0	3·0 pt.
D.D.T.	25%	0·138	6·6	26·4 oz.
		0·275	13·2	52·8 oz.
		0·45	26·4	105·6 oz.
		0·90	52·8	211·2 oz.
Dieldrin	18%	0·05625	2·7	15·0 oz.
		0·1125	5·4	30·0 oz.
		0·225	10·8	60·0 oz.
		0·45	21·6	120·0 oz.
Pyrethrum	6% Synergized with piperonyl butoxide 4·1	0·006	0·29	4·8 oz.
		0·06	2·9	48·3 oz.

TABLE 7

(25 × 6 *egg masses collected directly after spraying*)

Treatment	Total larvae emerged	Mean No. per egg mass of larvae emerged	Mean No. per mass of failures	Mean mortality
B.H.C.				%
0·03125	1,680	11·05	4·27	27·87
0·0625	2,082	14·07	5·76	29·05
0·125	462†	3·08	14·34†	82·38
0·25	9†	0·59	19·76†	97·10
D.D.T.				
0·158	2,006	13·66	3·69	29·42
0·275	1,822	11·91	8·28	41·01
0·45	1,643	11·03	7·03	38·92
0·90	1,811	11·76	5·31	31·11
Dieldrin				
0·0562	2,058	13·45	4·97	26·98
0·1125	2,395	14·60	3·77	20·61
0·225	1,890	11·96	6·33	28·73
0·45	2,047	13·65	5·01	26·85
Pyrethrum				
0·006	1,936	12·18	6·96	35·84
0·06	1,942	13·49	6·50	32·52
S.E.	±261·36		±1·03	

*Significant response P = 5%
†Significant response P = 1%

TABLE 8

(15 × 5 *egg masses collected eight days after spraying*)

Treatment	Total larvae emerged	Mean No. per egg mass of larvae emerged	Mean No. per egg mass of failures	Mortality
B.H.C.				%
0·03125	1,170	18·57	5·98	24·36
0·0625	1,098	16·89	4·00	19·15
0·125	1,033	15·89	5·12	24·34
0·25	1,034	14·56	5·28	26·61
D.D.T.				
0·138	917	14·32	6·22	33·59
0·275	944	14·98	5·58	27·14
0·45	918	14·12	6·60	31·85
0·9	1,070	16·71	5·10	23·38
Dieldrin				
0·0562	889	13·27	6·88	34·14
0·1125	943	14·73	5·84	28·39
0·223	926	15·41	6·62	30·05
0·45	1,033	15·65	5·72	26·77
Pyrethrum				
0·006	1,144	16·82	5·96	26·16
0·06	1,054	15·50	8·30	34·87
Control	922	14·87	6·16	29·31
S.E.	±100·1		±1·165	

NEMATOCERUS sp. (nr. brevicornis Hust.)—A PEST OF CEREALS IN KENYA

III—LABORATORY TESTS WITH INSECTICIDES AGAINST THE NEWLY HATCHED LARVAE

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(*Received for publication on 20th March, 1961*)

Preliminary attempts to control the larvae of *Nematocerus* sp. in cereals involved field trials with seed treatments applied at various rates and with surface application of sprays [1]. These proved unsuccessful and, with the increasing importance of the insect, laboratory studies were undertaken to discover the relative toxicity to the larvae of a number of insecticides and hence those which were most likely to prove effective in the field.

1. *Method of Testing Insecticides*

The larvae live in the soil and observations showed that they had to be kept in this or a similar medium; larvae kept in glass dishes or on damp surfaces died within 24-36 hours. Tests were therefore conducted by placing larvae in moist soil containing a known proportion of insecticide and examining them for mortality after a period of 72 hours. Initial tests were performed with about 50 larvae placed in 25-30 gm. soil in an open dish, but, although two such tests are reported here, the difficulty of recoving larvae 1 mm. long from this bulk of soil was considerable and only 60-80 per cent recovery of larvae was obtained. Subsequently, a standard method was used, ten larvae being placed in a 2-in. × ½-in. tube with 1-2 gm. of treated soil. This facilitated searching, and permitted replication, but meant that tubes had to be either corked, enhancing any fumigant action, or left unsealed and "watered". The former technique was usually preferred because wetting the soil caused aggregation of particles and increased the difficulty of searching.

At the end of the test, the soil was tipped into a watch-glass and searched under low-power magnification. The larvae were picked out with blunt forceps and placed in a watch-glass where they were subsequently examined and classified as living (i.e. showing movement) or dead. The use of a third class "living but incapable of co-ordinated movement", was rejected as too subjective, but when a number of larvae were observed to be definitely morbid this fact was noted. Results are presented throughout as the overall percentage mortality.

No statistical treatment is shown since the mathematical significance of these tests is unimportant. The primary object of determining those insecticides which showed toxicity at a high dosage can be best attained by inspection of results and selection of those showing promise. The second purpose of determining the dosages at which toxicity decreases is similarly served by inspection of results. However, it may be noted that several tests were subjected to the normal analysis of variance, and the coefficient of variation of the mean of five replications usually fell between 10 per cent and 20 per cent.

Preparation of Treatments

The soil treatments were prepared from commercial formulations since these were the only sources available and would be the type of formulation used in practice (*vide* Appendix I). Liquid formulations were prepared by progressive dilution in distilled water to ten times the concentration required in the soil. 10 ml. of the solution were then added to 90 gm. of air-dried, seived soil (maximum particle size 1.0 mm.) in a 4-oz. tin which was then sealed and shaken vigorously. The resultant mixture was checked by eye for homogeneity since unmoistened soil was easily distinguished. In a few cases, e.g. Baytex, lead arsenate. Sevin, only dry formulations were

available and these were prepared by progressive dilution in soil, the ultimate dilution allowing for the addition of 10 ml. of distilled water to bring the weight to 100 gm. Controls were prepared by adding 10 ml. water to untreated soil.

In tests denoted as 2 and 7, the stock prepared for test 1 was progressively diluted in soil without adjustment for moisture content. This has no significance in test 2, since the soil was subsequently watered, whilst it seems unlikely that lack of moisture has materially affected the results of test 7.

1. *Preliminary "Screening" Tests*

Test 1.—Soil mixtures containing 100 ppm. insecticide were prepared from liquid formulations and placed in small dishes to which 50 larvae were added. The dishes were watered and covered with a sheet of glass. After 72 hours the dishes were examined, larvae which had failed to enter the soil being picked off first and then the soil carefully examined. Despite the greatest care, it was only possible to recover some 60 per cent of the larvae introduced to the dishes and therefore the results are shown as percentage mortality in the larvae recovered from the soil, and apparent percentage mortality of those introduced, excluding those recovered from the soil surface. The results (Table 1) show low survival in the gamma B.H.C., D.D.T. and Metasystox treatments.

Test 2.—Mixtures containing 25 ppm. insecticide were made up from the stock mixture used in test 1 by diluting it in the ratio 1:3 in untreated soil. The procedure adopted was the same as for test 1. The results (Table 1) obtained after 72 hours, confirm the toxicity of gamma B.H.C. and D.D.T. Metasystox is less effective, whilst heptachlor and dieldrin are ineffective.

TABLE 1

(1 × 50 *larvae*)

	TEST 1		TEST 2	
	Mortality in larvae recovered	Apparent mortality of larvae inserted	Mortality in larvae recovered	Apparent mortality in larvae inserted
	%	%	%	%
gamma B.H.C.	95·6	97·7	100	100
D.D.T.	96·5	97·9	76·4	83·3
Metasystox	85·0	91·7	46·9	60·3
Dieldrin	42·8	63·6	3·0	19·6
Heptachlor	29·7	46·3	5·7	30·0
Control	16·6	54·5	7·7	36·8

Test 3.—Subsequent to the two foregoing tests the standard procedure for tests was adopted. In Test 3, the insecticidal mixtures were made up to give 25 ppm. in soil, and were placed in 2-in. × ½-in. tubes with ten larvae each and were sealed for 72 hours. The results (Table 2) reveal Baytex and Metasystox as the only insecticides of promise.

Test 4.—A similar test to test 3 was inaugurated later to test several further compounds. This differed from the previous test in that the tubes were left unsealed for 10-12 hours, and were then lightly "watered" with distilled water and sealed for 60 hours. The effect of this treatment on the results cannot be assessed, but it is most unlikely that it would render ineffective a potentially effective compound. The results (Table 2) show that none of the compounds were sufficiently toxic to warrant further examination.

Test 5.—In a further test, using the same technique as in test 3, pyrethrum, rogor and diazinon were tested, and all three gave high mortality after 72 hours at rates of the order of 25 ppm., whilst pyrethrum was ineffective at a tenth of the dosage.

TABLE 2

Test 3 (5 × 10 *larvae*)

Compound (25 ppm.)	Mortality
	%
Baytex	45*
Dieldrin	4
Endrin	0
Heptachlor	0
Metasystox	52
Sevin	6
Control	2

*Remaining 55% of larvae very sick and moribund.

Test 4 (5 × 10 *larvae*)

Compound	ppm.	Mortality
		%
Chlordane	25	10·9
Lead arsenate	100	13·6
Malathion	25	22·9
Toxaphene	25	12·5
Control	—	6·3

TABLE 2—(*Contd.*)

Test 5 (5 × 10 *larvae*)

Compound	ppm.	Mortality
		%
Pyrethrum	24	96·4
Pyrethrum	2·4	2·2
Diazinon	30	100
Rogor	25	97·6
Control	—	36·6

Summary of Screening Tests

Of the compounds tested, Baytex, gamma B.H.C., D.D.T., Diazinon, Metasystox and Rogor showed promise. Of these, the first three were considered worthy of further evaluation, whilst Metasystox was further examined as a representative of the systemic organic phosphate group.

2. *More Detailed Tests*

As a result of the foregoing tests, Baytex, gamma B.H.C., D.D.T., and Metasystox were selected for test at lower concentrations. Baytex only became available towards the end of the tests, and for this reason, and because no information on its likely market price was available, only one test was performed. This is described first.

Test 6.—Soil mixtures of Baytex were made up by the dry method to give concentrations of 5, 10, 15, 20 and 25 ppm. The tubes were left unstoppered for 12 hours and then watered and sealed for 84 hours. On examination, high mortality was found in the lower treatments, reaching 100 per cent at 15 ppm. and therefore it was considered unnecessary to make a quantitative assessment of the two highest rates. The results (Table 3) indicate that, provided reasonable persistence in the soil can be expected, the compound is worthy of field testing. The higher mortality with lower rates of application as compared with test 4 may be explained by the increased exposure period (96 hours against 72 hours).

TABLE 3

(5 × 10 *larvae*)

ppm. Baytex	Mortality
	%
25, 20	Apparently 100 (qualitative estimate)
15	100
10	81·6
5	71·1
Control	9·5

Test 7.—Insecticide/soil mixtures of gamma B.H.C., D.D.T. and Metasystox were made up by progressive dilution of the stock used in test 2, to give concentrations of 10, 5 and 2.5 ppm. No adjustment for moisture was made, but otherwise the standard procedure was followed. The experiment was examined after 72 hours and the results (Table 4) showed gamma B.H.C. to be highly effective at all concentrations, D.D.T. decreasingly so and Metasystox ineffective.

TABLE 4

(5 × 10 *larvae*)

Compound Concentration (ppm.)	Percent mortality 10	5	2·5	0
gamma B.H.C. ..	100	100	85·7	12·5
D.D.T.	61·5	38·0	20·7	
Metasystox ..	10·0	11·8	14·7	

Test 8.—D.D.T. and Metasystox were further examined at similar rates to that in the previous test, but the soil mixtures were prepared direct from fresh aqueous solutions. The results (Table 5) tend to confirm those of test 7 although rather higher mortality occurred in the D.D.T. treatments. As a result of this and the preceding test, gamma B.H.C. only was selected for further test.

TABLE 5

Compound Concentration (ppm.)	Percent mortality 10	5	2·5	0
D.D.T.	76·6	82·6	58·5	36·4
Metasystox ..	44·7	36·4	27·3	

Test 9.—Using fresh solutions, soil mixtures were made up to give 10, 5, 2.5 and 1.0 ppm. gamma B.H.C. Six replicates of each treatment and a control were set up and two replicates of the 10, 5 and 2.5 treatments and the control were examined after 72 hours, and the remaining four replicates after 96 hours (except that two replicates of the 10 and 5 ppm. were ignored). In the 1 ppm. treatment, all six replicates were examined after 72 hours. Two replicates were abandoned because of high mortality, a third

was accidentally destroyed and the remaining three were re-established for a further 24 hours. The results (Table 6) showed increased mortality during the extra 24-hour period, and high mortalities with the three highest concentrations. The 1 ppm. treatment did not differ greatly from the control.

TABLE 6

(10 *larvae per replicate*)

Time	Concentration of gamma B.H.C. (ppm.)	10	5	2·5	1	0
Hr.						
72	No. of replicates	2	2	2	6	2
	Percent mortality	80·0	73·7	52·6	44·4*	47·0*
96	No. of replicates	2	2	4	3	4
	Percent mortality	94·7	93·3	82·8	32·9	32·4

*Heavy mortality in two out of six replicates (1 ppm.) and one out of two (0).

Test 10.—As a corollary to test 9, the 1 ppm. mixture was compared with a control and with two series of freshly prepared 1 ppm. mixtures. The results after 72 hours showed no difference in mortality between any of the treatments. The respective mortalities were:—

Stock from test 7 ..	16.0%	
Freshly prepared stock	12.0%	16.0%
Control	14.3%*	

(* Figures derived from 5 × 10 larvae.)

Test 11.—Gamma B.H.C. was tested at five concentrations between 5 and 1 ppm. using the standard procedure. After 72 hours relatively high mortality was found in all treatments except the control (Table 7), but it was observed that the survivors in the 1 ppm. treatment were still vigorous and active whereas those from the highest treatments were moribund.

Test 12.—Test 9 was repeated, but this time the tubes were left unsealed for 12 hours and then watered before being sealed. The mortality after 84 hours (Table 7) was much lower than in test 11 on the two lowest treatments, and the survivors appeared healthy, especially on the 1 ppm. treatment.

TABLE 7

Concentrations of gamma B.H.C. (ppm.)	Test 9 (5 × 10)	Test 10 (5 × 10)	Test 11 (5 × 10)	Test 12 (10 × 10)
5	60·4	71·7	—	—
4	62·2	70·2	—	—
3	65·2	50·0	—	—
2·5	—	—	28·9	—
2	58·3	23·9	—	18·4
1	41·7	17·0	12·8	24·4*
0	4·2	†	6·1	15·2

*Includes 2 replicates with 100% mortality.

†Control omitted due to insufficient larvae.

The comparative mortality in these two tests indicates that the presence of water is impairing the action of the B.H.C. at lower concentrations.

Tests 13 *and* 14.—Two small tests, the first with 2.5 and 1 ppm. gamma B.H.C./soil mixtures, and the second with 2.0 and 1.0 ppm. gamma B.H.C./soil mixtures were set up. In neither test was there very high mortality (Table 7) after 72 hours (test 13) and 72-84 hours (test 14).

Test 15.—In a further small test, a 5 ppm. gamma B.H.C. in soil mixture was prepared by the dry mixing technique from a 2.6 per cent dust. After 72 hours, only 30.2 per cent mortality had occurred in 5 × 10 larvae against 2 per cent in the control, whilst a further 20.9 per cent of larvae were definitely sick. The lower mortality as compared with previous tests is probably due either to the greater difficulty of obtaining a reasonably homogeneous mixture in dry mixing or to the dust being rather more stable and hence having a slower fumigant action.

Test 16.—The foregoing results with gamma B.H.C. were obtained using commercial formulations containing adulterants, e.g. diluents, wetters, stickers. It was desirable to determine whether these other compounds had produced any effect and therefore a test was conducted with pure gamma B.H.C. (Lindane). The solid was dissolved and diluted in petroleum ether and the requisite quantities to produce concentrations of 5, 2.5 and 1 ppm. in 10 gm. added to 90 gm. soil. These were mixed thoroughly and the ether allowed to evaporate before 10 ml. water was added. The standard procedure was followed, except that a record of larvae capable of co-ordinated movement

was kept. The mortalities after 72 hours (Table 8) show no significant departure from those obtained with the impure formulations and it is reasonable to assume that the gamma isomer is the chief toxicant.

TABLE 8

(5 × 10 *larvae*)

Concentration (ppm.)	Percent mortality	Percent larvae capable of co-ordinated movement
5·0	70·8	0·0
2·5	51·0	0·0
1·0	14·0	34·0
0	29·8*	38·3*
	(15·4)	(46·2)

*Figure includes one replicate with 100% mortality. The bracketed figures are for the remaining four replicates.

Test 17.—Observations on the previous tests showed that the larvae readily entered treated soil and this was confirmed by placing a number of larvae in a petri dish with a small pile of soil containing 3 ppm. gamma B.H.C. After 30 minutes all larvae had entered the soil and 12 hours later none had left it.

A small, non-critical test was conducted to see whether larvae would avoid or leave treated soil if untreated soil was available. One half of a glass block was filled with soil containing 2.5 ppm. gamma B.H.C., and the other half with untreated soil. 25 larvae were placed on each half and left for 24 hours before the soil was examined. The soil from each half was scooped out and the larvae picked off. 27 larvae were recovered from the B.H.C. treatment and 12 from the untreated, whilst 11 could not be found. Since the majority of larvae were very active, it is improbable that those found in the B.H.C. treatment were incapacitated and, therefore, it may be assumed that B.H.C. has no repellent effect. The converse, that B.H.C. is attractive, is unproven, since the number recovered from the treatment does not differ from the number inserted. The point was not considered of great value since the area over which any attractant could operate would be very limited in the field.

Test 18.—Only one test on older larvae was possible and even this was greatly limited since only 46 larvae three to four weeks old were available. Larvae were placed in tubes containing soil treated with 10 ppm. and 5 ppm. gamma B.H.C. and were compared with an untreated control. Five larvae were used per tube and each treatment was replicated three times. After 72 hours 100 per cent mortality had occurred in both treatments and none in the control.

Summary of Results

Of the 15 insecticidal compounds tested at a concentration of 25 ppm. in soil, only Baytex, gamma B.H.C., D.D.T., Diazinon, Metasystox and Rogor caused reasonably heavy mortality. D.D.T. and Metasystox were found to be ineffective when the concentrations were reduced whilst although Baytex showed promise even at 5 ppm. tests were not continued because of lack of information especially from the the marketing angle. Gamma B.H.C. was tested severally and the results obtained show heavy mortality down to *circa* 2.5 ppm., below which level survival increased rapidly and 1 ppm. was usually ineffective (tests 7 and 9-14.) There is a possibility that toxicity is dependent on formulation (test 15) and it is shown that the gamma isomer is the main toxic agent (test 16). There is evidence that gamma B.H.C. has no repellant action (test 17) and that rather older larvae are susceptible to concentrations of the same order as are newly hatched larvae (test 18).

Significance of these Results for Field Trials

The extrapolation from laboratory tests to field trials presents considerable difficulties, especially since in these tests the effect of the compounds as stomach poisons has not been examined. This effect may have little significance since the larva are definitely attracted to, and feed upon, the root systems of the plant, and are not likely to consume any quantity of treated soil. From the results obtained, the obvious insecticide to test is gamma B.H.C. and this will probably have to be applied to give a concentration of at least 2.5 ppm. (i.e. 1.5 lb. actual gamma B.H.C. per 1 in. acre) at the time larvae enter the soil. Furthermore, Lichtenstein and Schulz ([2] have shown that in some American soils, gamma B.H.C. is rapidly degraded to 50 per cent of the applied quantity and it may therefore be necessary to think in terms of applying 5 ppm. or even more at the time of planting. However, since larvae are attracted to the roots, and not repelled by

gamma B.H.C., heavy application with the fertilizer may provide a satisfactory and cheaper answer. It must also be remembered that these tests were conducted over a short period, and lower concentrations acting over a longer period may provide a control either through killing the larvae or affecting their viability.

Summary

Seventeen laboratory tests on the effect of insecticides in soil on newly hatched larvae are described, as well as one on slightly older larvae. Gamma B.H.C. is shown to be the most promising, causing considerable mortality at rates as low as 2.5 ppm. but, even so, it is doubtful whether the control of larvae by such methods will be an economic proposition.

References

[1] Bullock, J. A. (1960). *E. Afr. agric. for. J.*, 1961.

[2] Lichtenstein, E. P., and Schulz, K. R. (1959). *J. econ. ent.* lii (1). pp. 118-24.

Appendix

Insecticide formulations used as a source for tests, their assumed percentage content as specified by the manufacturer and the tests in which they were used.

Compound	Formulation	Assumed percentage content	Tests in which used
		%	
Baytex	Baytex 40 W.P.	40·0	4, 6
gamma B.H.C.	Agrocide 7 dust	2·6	15
gamma B.H.C.	Gammalin 20	20·0	1, 2, 7, 9–14, 17, 18
gamma B.H.C.	Lindane	99·0	16
Chlordane	Chordox	100·0	4
D.D.T.	Didimac 25	25·0	1, 2, 3, 7, 8
Diazinon	Diazinon 60E	66·0	5
Dieldrin	Supadiel	18·0	1, 2, 3
Endrin	Endrin dust	2·0	3
Heptachlor	Heptachlor E	24·0	1, 2, 3
Lead arsenate		100·0	4
Malathion	Malathion	50·0	4
Metasystox	Metasystox	50·0	1, 2, 3, 7, 8
Pyrethrum	Special formulation	6·0	5
Rogor	Rogor 40	40·0	5
Sevin	Sevin 50 W.P.	50·0	3
Toxaphene	Coopertox	75·0	4

THE PROBLEMS OF COCONUT PRODUCTION ON SEYCHELLES "OUTER ISLANDS"

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At present Seychelles exports about 5,000 tons of copra each year and this provides, directly and indirectly, most of the Colony's income. Over one-third of this copra is produced on plantations in the "Outer Islands" and is shipped to Mahe for grading prior to export. Agricultural conditions on these islands are somewhat unusual for, although coconuts are popularly associated with "coral islands", they are usually grown there as a peasant crop rather than on a plantation scale. Because the soils are inherently infertile a number of agricultural techniques have been evolved over the last 60 years, some which may be of more general application.

The Islands

The main copra producing "outer islands" are: (*a*) Denis and Bird, situated on the northern rim of the Seychelles Bank; (*b*) the Amirantes including Remire, Daros, Poivre, Des Roches and Marie Louise; (*c*) Coetivy; (*d*) the Alphonse Group; (*e*) Providence; and (*f*) Farquhar. There are both atolls and reef islands, but their mode of formation has been similar. Submeregd algae and corals have grown to the surface of the Indian Ocean where they have been broken and pulverized by wave action. Where conditions were favourable the resulting sand and gravel emerged above sea level and eventually became stabilized by vegetation. Even so the islands are ephemeral on a geologic time scale. They are continually being eroded away by the sea in places, whilst build-up of additional land occurs elsewhere as currents change.

Coetivy, a long narrow sand-cay, is the largest cultivated island, being over 1,500 acres, whilst the smallest is probably Remire, which is no more than 100 acres. With the exception of Remire and Marie Louise, which are Crown Lands, all these islands are privately owned, but none are permanently inhabited. All labourers are employed on a two-year contract at the end of which they are compelled to return to Mahe.

Environment

Farquhar is 430 miles from Mahe, the main island of Seychelles, but the others are less. Their climate is, however, similar. Rain can be expected between December and May, but for the remainder of the year during the south-east monsoon it is unusual. Records have been taken for only a few years, but a typical example is Daros, in the Amirantes, which has an eight-year average of 55.26 in. Sunshine hours are high and sunless days are rare. From December to May the islands are in the "doldrums" with light variable winds but for the remainder of the year the winds are moderate to strong, averaging between 10 and 20 knots, and almost constant in direction. Unfortunately the two most southerly islands, Providence and Farquhar, are on the edge of the cyclone zone and have occasionally suffered considerable palm losses from high winds.

Soil and Water Supply

All soil on the coral islands is alkaline and contains up to 95 per cent calcium carbonate. With the exception of very small quantities of sea-borne pumice igneous rocks and their weathering products are entirely absent. The main soil type is a sand, or gravelly sand, similar, if not identical, to the Shioya series described by Stone [1] on Arno atoll in the Pacific. Such soil is alkaline and extremely free draining. The content of organic matter in the top few inches rarely reaches 1 per cent, and more commonly is in the region of 0.2 per cent, whilst below 12 in. it is negligible. There is virtually no clay fraction and the content of nutrient elements other than calcium, magnesium and phosphorus is minimal. The phosphorus content in this soil may reach 5 per cent P_2O_5 in certain places where there have been numerous sea-birds.

A cemented layer is common at the water-table, especially near the coast where the ground-water may be saline, and this is identical with the hard "beach sandstone" often found exposed on the shore at high tide mark. Cementation is due to precipitation of calcium carbonate from bicarbonate present in percolating rain-water and this horizon is only slightly permeable to water and forms a complete barrier to roots. Where there has been a thick layer of superficial guano a second type

of cementation occurs with calcium phosphate as the main cementing agent. Below the guano there is rarely less than 6 in. of cemented phosphatic sandstone. A second phosphatic layer occurs near the water-table and, on some islands, these two layers are continuous, with sandstone from the surface to the water. Below water there is invariably unconsolidated sand. Owing to traces of plant nutrients in the original guano any soil formed under these conditions is relatively fertile.

One other soil type occurs on Farquhar where a number of both high and low sand dunes occur. The origin of the dunes is somewhat obscure, but they probably result from both wind and wave action during high winds. The sand is uniform but fine and, on the older dunes, a distinctive profile has developed due to accumulation of organic matter in the superficial horizon.

Except where there is a cemented horizon, all soils are very permeable to water and the water-table rises and falls with the tide. Rain rapidly penetrates to this water-table, run-off being negligible. There is little mixing with the sea-water and there remains a lens of "fresh" water perched on the salt water below. Other factors being equal the thickness of the lens depends on the distance from the shore line. Thus, abundant supplies of fresh water are available in the centre of large islands, but on narrow spits of land the ground-water is saline. Luckily, the coconut is a semi-halophyte and can withstand a surprising concentration of salt in the ground-water.

Agriculture

Some vegetables and tobacco are grown for personal consumption, whilst a little maize is often planted to feed poultry and other livestock, but copra is the only export. It is difficult to establish the planting date of the coconuts as few records are available, but it is not improbable that wild palms have been established on the coasts for many centuries. Some planting must have been carried out around 1870 for Gardiner and Cooper [2] reported that the plantation of Farquhar was destroyed in 1893 by a cyclone whilst in the same paper a photograph of Poivre Island in 1905 shows palms at least 30 years old. The island records at Alphonse show that much new planting was carried out in 1910-12, but Dupont [3] records that in 1905 the island was producing some 300,000 nuts a year!

However, it is only on one island that palms show signs of excessive age; Poivre. Here, as on several others, under-planting has been carried out not once but twice in places. In the early days the nuts were planted in shallow holes, but this was soon found to be unsatisfactory and the following system has been developed. A hole is dug to below the water-table and, owing to the limited stability of unconsolidated sand, it may be 10 ft. wide at ground level. As decomposition takes place the hole is refilled over a period of some six months. After this no refilling takes place and a seedling is planted in the rotted debris some 9-12 months after digging. It is usually about 18 in. below the surface, but on some islands where the water-table is deep, planting may be 6 ft. down and the sides of the hole have to be walled with husks to prevent the seedling being buried. On Farquhar, the only island partially mechanized, the initial hole digging is carried out by a power-driven auger 3 ft. in diameter, and there palm spacing is maintained at 9 yd. On other islands the spacing tends to be much closer; any obvious gap being filled with a seedling.

After this initial preparation a young palm should come into bearing after about seven years, but rarely does when it has been underplanted in an existing plantation, for owners are reluctant to fell the old palms. The young palm becomes tall and "leggy", with all the leaves at an acute angle to the trunk and well over a foot between the leafscars. Bearing under these conditions is delayed indefinitely.

In a mature plantation annual slashing of undergrowth is carried out whilst all organic debris such as fallen leaves and husks is buried either in long trenches or in "manuring" holes. These latter are pits dug to the water-table, close to the trunk of the palm, similar to planting holes. Such a pit is made every ten years or so for each palm, the objects being to (*a*) open a passage for the roots to reach water in case cementation has occurred; (*b*) encourage the formation of new roots; and (*c*) utilize available manuring material. As a treatment it is highly successful. Poorly bearing palms are rejuvenated within months and the benefits outweigh the high costs. It is only within the last two years that inorganic fertilizers have been used, and then not on a large scale.

All nuts are allowed to fall and are collected at more or less weekly intervals, being husked in the plantation. On arrival at the main settlement the nuts are broken and the meat extracted.

Various methods of drying are used depending on the season and the facilities available. Generally the meat is placed in a shallow layer on wire mesh trays in a locally made hot-air drier—calorifere—for two to three days. The initial drying is fast and much of the moisture is lost within the first 48 hours. If the weather is cloudy or wet final drying is carried out in the same "calorifere" at a lower temperature (by moving the copra further from the source of heat) for an additional three to four days, but in fine weather the remaining moisture is removed by sun drying for up to eight days. By these methods a good quality product is almost always obtained. The moisture content of the copra has to be very low in view of length of storage time sometimes necessary before the arrival of a schooner.

Pests and Diseases

On small isolated islands the introduction of pests and disease pathogens can, with care, be prevented, and it should only be necessary to eradicate those already present. However complete eradication is often difficult. Environmental changes or climatic abnormalities may induce a rapid increase in incidence whilst chance introductions can still occur.

As an example of the latter, during the last year a small outbreak of rhinocerous beetle (probably *Oryctes monoceros*) occurred on Farquhar, which was previously free of this pest. Prompt action was taken to destroy all the adults and larvae and it is now presumed to have been completely wiped out. Where a heavy infestation has been allowed to build up, as on Poivre, eradication is extremely difficult. At present Farquhar, Providence and Marie Louise are free of rhinoceros beetle, the others having varying degrees of infestation. Attempts at control by the introduction of Scoleid wasps (*Scolia ruficornis*) from North Island [4] have had little success on Poivre and the only economic means of control are by estate hygiene and destruction of individual insects.

Other pests, now under control, are scale insects [4]. Occasional outbreaks still do occur but reimportation of the coccinellid predators is extremely effective in reducing the population. Unfortunately similar success has not been recorded so far for biological control of the long-tailed mealy bug (*Pseudococcus adonidum*) on Poivre and Daros, where it remains a serious problem. Luckily, *Melittoma insulare* has not been introduced on the Outer Islands. It is the most serious pest of granitic islands and its control is expensive and time-consuming when a large population has built up, whilst it is difficult to detect when the numbers are few and infestation not expected.

Pathogenic diseases are of little interest. Stem bleeding is not uncommon, but causes little damage, whilst cases of "bud rot" and "leaf rot" have been recorded. The owners' self-imposed restriction on the importation of coconut leaves and similar material to the islands in order to prevent the introduction of insect pests has also been effective in preventing entry of disease.

Physiological "diseases" are, however, common. Tapering stems are the rule rather than the exception on the older palms, whilst leaf chlorosis is usual on the nutrient-deficient sandy soils. The control of these diseases is a matter of plantation management and the improvement of soil fertility.

Discussion

On coral islands there are, excluding pests and diseases, two main agricultural problems, namely conservation and use of available water and improvement of fertility. Whilst these are common to much of the world's agricultural land the problems are accentuated on these small islands where there are no reserves.

The only water storage is in the soil and the storage capacity is limited by the size of the island; the thickness of the fresh water "lens" being determined by the relative density of fresh and salt water. Whilst the coconut can tolerate a surprising percentage of salt in the groundwater, it cannot thrive on sea water alone. Menon and Pandalai [5] suggest that minimum annual rainfall for reasonable growth is 40 in., evenly distributed, or more if the fall is seasonal. The island rainfall is not only seasonal, but it is very variable and a succession of dry years could be serious. It is probable that the large number of holes. filled with organic matter, increase the water holding capacity of the topsoil to some extent whilst they certainly provide a channel for the roots to penetrate deep in the subsoil to tap the water-table. Examination of the root systems of mature palms confirms that there is little downwards growth in the sand, but the rubbish-filled holes have a dense network of roots to a considerable depth. The annual slashing of the undergrowth also aids water conservation by reducing the transpiration loss.

The maintenance and improvement of fertility is a much more difficult problem. The

total weight of individual nutrients on an island is, with the exception of nitrogen, fixed. Weathering of the calcareous sand produces calcium, magnesium and some phosphate but little else, whilst there is no possibility of the nutrient content being increased by deposition of silt on erosion debris from elsewhere. As most islands are completely planted the only value of livestock and animal manure is in moving nutrients from one place to another and leaving them in a more available form rather than increasing the overall fertility.

In addition there are many factors operating which cause a direct loss of nutrients. The soil is freely drained and leaching losses are high whilst the alkalinity indicates that many nutrients are in forms unavailable to plants. It is, however, the export of copra which is causing the biggest loss. On Denis, for example, in the 100 tons of copra exported each year, the annual losses of nitrogen and potassium are approximately 2.5 tons and 0.8 tons, respectively, whilst minor elements which, by nature of the soil forming process are present at low concentration, are also removed from the island.

The only addition to the nutrient reserve is in the rations imported for the labour, but the residues from these tend to be concentrated in pit latrines and available to only a few palms. It is unfortunate that little use is made of fish and turtle residues. On many islands the catch is heavy, but waste products are always disposed of in the sea, probably for hygienic reasons.

The nutrient status of the soil is, therefore, decreasing slowly. However, the agricultural techniques are helping to conserve fertility as much as possible and yields are not yet declining seriously. The burying of organic matter in the planting and "manure" holes concentrates fertility near the palm where it is needed and by also allowing root penetration to the water-table enable the palm to tap any nutrient salts in the ground-water. Some husks are burnt in the calorifere, but burning of other vegetation is discouraged and all the ash produced is returned to the soil.

Any form of agriculture on these islands must reduce the fertility and conventional methods of maintaining the nutrient status of the soil by making use of elements by weathering of the parent material are inapplicable. The relatively high coconut production at present is only possible because the soils have never been cropped before and yields must inevitably decrease as the meagre reserves are used up. Inorganic fertilizers seem to be the answer to this. They would not only replace the nutrients which have already been lost, but should increase the copra production to a marked extent and result in direct profits. A detailed experimental programme is now in progress to discover the immediate fertilizer needs and to estimate the probable return. As the copra from these islands provides much of the territory's revenue the successful outcome of this work and the adoption of a regular fertilizing programme by the planters could help future economic development.

References

Stone, E. L. (1951). The Soils of Arno Atoll, Marshall Islands. *Atoll Research Bull. 5*, 1-56.

Gardiner, J. S., and Cooper, F. F. (1907). Description of the expedition. *Trans. Linn. Soc. Zool. 12*, 111-175.

Dupont, P. R. (1929). Report on a visit to the Outlying Islands. Government Printer, Seychelles.

Lionnet, J. F. G. (1958). A review of the biological control of agricultural pests in the Seychelles. *E. Afr. agric. for. J. 24*, 254-256.

Menon, K. P. V., and Pandalai (1958). The coconut palm. Indian Central Coconut Committee. Page 111.

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